Volume 1

Chapter 4 – Planning for an Uncertain Future

Chapter 4 Preparing for an Uncertain Future

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Water is a vital natural resource for people and the environment. Water managers must support environmental stewardship as part of their management responsibilities. (DWR photo)

Chapter 4 *Preparing for an Uncertain Future*

About This Chapter

Chapter 4 Preparing for an Uncertain Future describes how the State of California is adapting to the changing needs of decision-makers, water managers, and planners. It lays out a new analytical approach and multiple future scenarios. The Department of Water Resources (DWR) will use these to develop and share information essential for making many difficult choices about how to manage California's water resources over the next 25 years.

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A Common Approach

California's water management system is large and complex. Making wise choices will require a great deal of cooperation and collaboration among decision-makers at all levels. State, federal, regional, and local entities throughout California will have to make many decisions to implement the Framework for Action as described in Chapter 2. The framework's foundational actions, initiatives, and essential support activities are central to ensuring that California has sustainable water uses and reliable water supplies through 2030.

Our decisions must include making sound investments that balance risk with reward, given the uncertainties that may occur in the future. Some of the risks associated with potential changes in California's future run quite high and require our consideration. Fortunately, the potential rewards are equally compelling, and a broader understanding of these opportunities can help people work together for collective gains.

People can work together more effectively if they all have access to the same information. **As part of this and future California Water Plan updates, DWR is promoting ways to develop a common conceptual framework, data standards, and analytical approach for understanding, evaluating, and improving regional and statewide water management systems.** A common analytic approach is particularly important when multiple agencies are proposing actions that may compete for the same resources. This can occur, for example, when State government solicits funding proposals for water management projects or when agencies identify new management strategies for meeting future water demands. It is difficult to evaluate the benefits and impacts of multiple projects that affect the same water management system when the projects are not described using a common analytical framework.

Changing Times, Changing Questions

Decision-makers and the public are asking different questions than those addressed in earlier California Water Plan updates. This reflects the increasing complexity and interdependence of managing California's water resources for all our human and environmental needs. Recent scientific studies indicate that there is a great deal of uncertainty about future climate conditions like the severity of droughts and global climate change. We know that climatic conditions can affect our water supplies—but how and to what extent? Our water supplies face increased competition from a population that is growing by about 600,000 a year and from our desire to protect and enhance the environment and maintain our agricultural production.

As in other areas of our lives, we routinely rely on timely and trustworthy information to make prudent, high-stake decisions about how and where to best use our water resources and funding. While preparing Update 2005, DWR worked extensively with a broad range of stakeholders to identify their information needs for improving water planning and management. DWR asked what information local and regional water agencies and governments need to plan and successfully implement actions to meet water demands now and in the future, and what information would be most useful to assess risk and rewards regarding public and private investments in our water resource management systems. DWR also addressed the role that State government should play in helping produce and distribute this information.

Information Needs

DWR conducted a series of public workshops to understand the kind of information most needed by decision-makers, water managers, and planners (see Box 4-1 Desired Information for the California Water Plan). Topics included what we want to accomplish with our water resources, the current water management system and how it might be changed, what the future may hold and how to prepare for future uncertainties, how statewide and regional water and resource planning overlap, and how different approaches to preparing for the future compare to one another in light of our objectives and available resources.

Existing Limitations

Several factors have led DWR to rethink how it evaluates California's future water conditions. There is a need to provide policymakers and the public with more detailed quantitative information about the costs, benefits, and tradeoffs associated with different water management strategies. See Box 4-2 Types of Quantitative Information for definition of four types of quantitative information that the California Water Plan can provide. **Data, analytical tool development, and data management have not kept pace with growing public awareness of the complex interactions among water-related resources.** Finally, California lacks a consistent framework and standards for collecting, managing, and providing access to data and information on water and environmental resources essential for integrated regional resource management. More accurate data and analytical tools and better information management

Box 4-1 Desired Information for the California Water Plan

What do we want to accomplish with our water resources?

- Economic Objectives
- Environmental Objectives
- Equity Objectives

How does the current water management system work now and how might it change with respect to the following?

- Water use and environmental interactions
- Basic hydrology including groundwater
- Economics, price, and water use
- Interregional transfers
- Quantity and quality interactions
- Water law considerations
- Changes in technology that can affect water supply reliability

What can we expect to happen in the future? What are we preparing for?

How can we consider uncertainties about the future when making a decision?

- How will water management system performance change with respect to water supply reliability, water quality, and ecosystem health goals when faced with different circumstances?

How does (and should) regional and statewide water and resource planning intersect?

How do different approaches to prepare for the future compare to one another in light of our objectives and available resources? What are the expected tradeoffs?

can reduce many uncertainties about the state's current and future water resources: how water supplies, demands, and water quality respond to different resource management strategies; how ecosystem health and restoration can succeed; and how we can adapt our water system to reduce controversy and conflicts.

The need for enhanced quantitative information is not unique to the California Water Plan update process. The CALFED Surface Storage program and the California Water and Environmental Modeling Forum (CWEMF) have also identified the need for more integrated data and analytical tools, and more accessible and robust information management systems. Some areas where data and tools are inadequate for the analyses we need to conduct are described below and are further elaborated in Volume 4 article, "Improving Analytical Procedures Used to Describe Future Water Conditions for the California Water Plan."

Data Gaps

Data are needed to complete regional waterflow diagrams (see Volume 3 Regional Reports). Flow diagrams characterize a region's hydrologic cycle. Completing regional flow diagrams and water balances requires more detailed land and water use data and the ability to differentiate between applied and consumptive water uses. The following categories of data are simply not available or require a large amount of work to compile.

- Statewide land use data - native vegetation, urban foot prints, nonirrigated and irrigated agriculture
- Groundwater - total natural recharge, subsurface inflow and outflow, recharge and extractions, groundwater levels, and water quality
- Surface water - natural and incidental runoff, local diversions, return flows, total streamflows, conveyance seepage and evaporation, and runoff to salt sinks
- Consumptive use - evaporation and evapotranspiration from native vegetation, wetlands, urban runoff, and nonirrigated agricultural production

Data are available for some regions and not others. For example, methodologies and data to estimate natural runoff are available for regions like the Sacramento Valley where the Sacramento-San Joaquin Delta is a central outflow measurement. In areas like the South Coast Hydrologic Region, with no central point for outflow measurement and substantial groundwater, the natural runoff is more difficult to estimate. In addition to natural obstacles, existing data are not easily gathered or split apart to provide convenient access for all areas of interest. In addition, budget constraints limit extensive data collection and management necessary to quantify and track all the water in the state. (See Volume 4 Reference Guide article "Future Quantitative Analysis for California Water Planning" for a more comprehensive description of data gaps.)

Box 4-2 Types of Quantitative Information

To promote clarity and common understanding, we have defined four types of quantitative information that the California Water Plan can provide.

Observable data. This information is discrete data that can (or could) be measured or observed at a particular place and time. We also presume that if we could measure it in the future, we can predict what the values might be in the future.

Causal relationships. This information is what we believe to be true, or at least our best guess, about how different observable data are influenced by other factors, for example, How does urban water demand change with regard to shifts in prices charged to the consumer?, or How does groundwater production in Glenn County change with regard to temperature during the growing season for rice? Our entire understanding of how the water management system functions can be described using observable data and causal relationships.

Reporting metrics. This information contains a combination of observable data in a clearly defined way, for example, water supply reliability is reported as a function of water demand, water delivery, time, place, etc.

Evaluation criteria. This information describes the standard by which reporting metrics will be judged, for example, if water supply reliability is less than some threshold value during dry and critical years then additional management actions are required.

Fragmented Water Information

California needs better data and analytical tools to produce useful and more integrated information on water quality, environmental objectives, economic performance, social equity objectives, and surface water and groundwater interaction. Today, it is difficult to compare, much less integrate, water data and information from different local entities to understand and resolve regional and statewide water management issues. **To make significant progress toward a more comprehensive scientific understanding, California needs to create a new information exchange and management system and more integrated analytical tools** that can be used to document and share knowledge as it is developed.

New Analytical Approach

Current data and analytical tools are not sufficient to provide answers to some important questions from decision-makers, water managers, and resource planners. DWR is working with others to develop a new analytical approach to prepare the next California Water Plan update. DWR, CWEMF, and others are working to ensure that California continues to develop enough data and data analysis, including information management systems and analytical tools, for making crucial decisions about water resource investments. CWEMF members have recommended approaches to address important needs (see Volume 4 Reference Guide article "Strategic Analysis Framework for Managing Water in California"). DWR also describes some next steps in the Volume 4 Reference Guide article, "Recommended Next Steps for Improving Quantitative Information for the California Water Plan". With its concept paper, DWR will begin discussions with other planning entities, decision-makers, and stakeholders for developing a long-term approach for improving data and analytical procedures essential for statewide water planning.

The following sections describe an approach for analyzing responses to an uncertain future. Box 4-3 Evolving Analytical Approach briefly compares how analysis was done for the last water plan update (Bulletin 160-98) and the general approach proposed in this update. Volume 4 Reference Guide article "Future Quantitative Analysis for California Water Planning," provides more discussion of this new approach.

Box 4-3 Evolving Analytical Approach

Since the California Department of Water Resources published the California Water Plan in 1957, DWR has continued to evolve analyses to meet changing information needs for subsequent water plan updates. Early in the series of Bulletin 160 updates, reports included water budgets (water uses, supplies, and shortages) for a typical (that is, trend-based) average water year. In the 1993 and 1998 updates, water budgets were also included for an extreme drought condition (a critical water year). Bulletin 160-98 estimated the magnitude of dry-period water shortages in different areas of the state and also presented some options for reducing those shortages.

Rather than using water budgets to show a gap between future uses and supplies, DWR and stakeholders now want a more comprehensive analysis that includes economics, water quality, and environmental and social considerations. (For more information on desired changes to DWR's analytical approaches see the article, "Improving Analytical Procedures Used to Describe Future Water Conditions for the California Water Plan" in Volume 4). Considering the large amount of work required to include these changes, the analytical work could not be completed for this water plan update. Without this analysis, Update 2005 lacks the information to make the types of region-specific water budget comparisons afforded by Bulletin 160-98. However, Update 2005 provides qualitative discussions and presents the analytical approach for use in future California Water Plan updates. If the past is any indication, we expect the analytical approach to continue to evolve long after the next update is completed. Some changes in the analytical approach proposed by California Water Plan Update 2005 include:

Approach

- Bulletin 160-98 used and expanded the analytical methods that were developed in Bulletin 160-93
- Update 2005 presents a new analytical approach for multiple future baseline conditions (scenarios) and alternative response packages for potential use in the next California Water Plan Update.

continued

Developing and providing more comprehensive information will take time. DWR, advisory committee members, and other stakeholders put a lot of thought into how to develop more useful quantitative information. A lot of discussions focused on "What to expect in the future" and "How to account for uncertainties when making a decision." DWR and stakeholders have made good progress developing a conceptual analytic framework to address these questions, and DWR staff has taken initial steps to identify and develop methods and tools necessary for the required analyses. Because time is needed to develop this new approach, most of the detailed quantitative work will be presented in the next California Water Plan update.

Producing broader and more integrated quantitative information is an ongoing process. DWR plans to lead an effort with other State, federal, and local entities to continue developing and refining information. Credible and relevant answers to these questions require significant advances in our approach to learning about the system, testing hypotheses about change, and sharing information. Achieving these advances requires significant investments in better information management systems, additional data collection, and more sophisticated, transparent, and accessible analytical tools. One of the primary aims of the next two water plan updates is to collaborate with recognized experts to develop a foundation for a quantitative water information system that will support water plan updates and serve water managers and planners well into the future.

Improving Data Management and Scientific Understanding

DWR has determined that designing the details of this progressive quantitative approach can best be achieved through a consortium of public and private entities, with State leadership and stakeholder input. The consortium should prepare a long-term plan to improve and peer review data and analytical tools, as well as to develop presentation and decision-support tools to make complex technical information more accessible to decision-makers and resource managers.

Box 4-3 continued from previous page

Current Conditions

- Bulletin 160-98 used trend analysis to normalize year 1995 to represent a typical average year.
- Update 2005 presents water portfolio (see Volume 3) information for three actual years (1998, 2000, and 2001). These three years do not allow drought or other planning analysis that will be possible after water portfolios for several additional actual years are developed.

Future Conditions

- Bulletin 160-98 projected a single future condition to year 2020 for land use, water demands, and supplies.
- Update 2005 presents an approach to consider multiple plausible, yet very different, future scenarios to year 2030 for analysis in the next California Water Plan Update. Update 2005 also presents the concept of alternative response packages for each scenario for analysis in the next California Water Plan Update.

Water Shortages

- Bulletin 160-98 computed the difference between water demands and supplies as the shortage.
- Update 2005 presents an approach to balance water demands and supplies for each response package by including economics, water quality, and environmental and social considerations.

Potential Future Management Strategies

- Bulletin 160-98 presented options that could be used to reduce shortages by area of the state.
- Update 2005 presents an approach to allow comparison of many different response packages at the regional level using evaluation criteria.

Response packages are different mixes of the resource management strategies (see Volume 2). All of these changes need to be supported by developing better data and analytical tools. Data and modeling results will be presented in the water portfolio format (see Volume 3).

Box 4-4 Principles for Development and Use of Analytical Tools and Data for California Water Problems and Solutions

Strategy

- Data and analytical and communications tools should be based on expected long-term water problems and the decision-making processes they are expected to inform.
- A strategic analysis framework should identify the technical objectives, roles, and responsibilities of major data collection efforts and analytical tools.
- Strategic documents should be prepared and made available to the public. They should undergo periodic internal and external review, with substantial input from stakeholders, to identify needs for additional analytical tool and data development.
- A frequently updated implementation document should outline short-term and long-term efforts, budgets, and responsibilities for continuous improvement of models and data. A sustained process for stakeholders input should be defined and adopted.

Transparency

- All data and models should have sufficiently detailed documentation.
- Known limitations and appropriate applications should be documented.
- Model applications should include explanatory & self-critical discussions of results, including uncertainty analyses.
- Data, models, and major reports should be in the public domain, available on the web, and regularly updated.
- A common glossary of key terms and acronyms should be maintained.

Technical Sustainability

- Modularity: Major analytical tools should be designed and implemented to fit modularly in the larger strategic analysis framework, allowing models to be tested, refined, updated, and replaced without major adjustments to other components.
- Adaptive information management framework: Major data and information efforts should fall within a larger information management framework, including protocols for data documentation and updating, and documentation of limitations.

Coverage

- The spatial coverage of the basic data and analytical framework should be statewide and encompass a wide variety of water management options and processes.
- Local and regional water management interests and resources should be explicitly represented to allow consistency among local, regional, and statewide studies.

Accountability and Quality Control

- Explicit testing should be done, documented, and available for major analytical tools.
- Protocols and guidelines for model use should be developed and adhered to.
- Major analytical products should be reviewed by both external experts and local agencies whose systems are included in the model(s).
- In developing and maintaining models, serious efforts should be made to involve local agencies and stakeholders, including users groups or other cooperation mechanisms.

DWR plans to build and maintain an online information exchange system—called the Water Plan Information Exchange (Water PIE)—to assist regional and local agencies and governments. It is intended to include information from locally developed urban and agricultural water management plans and local general plans. This type of online information exchange system will be designed to support regional partnerships by providing a common way of developing and sharing information. It will streamline development of integrated regional water management plans by providing a common vocabulary and a check list of the types and format of information needed to develop an effective plan. An information management system such as Water PIE will also enhance the opportunities for collaboration with academic and research institutions by improving access to the most current data and information throughout the state.

Developing a Long-Term Vision for Data and Analytical Tools

DWR is participating in an effort by CWEMF to develop a long-term vision for analytical tools and data. This effort has derived a number of principles to guide the development and use of data and analytical tools over the next 10 to 15 years (see Box 4-4 Principles for Development and Use of Analytical Tools and Data for California Water Problems and Solutions). The technical scope and magnitude of the desired analyses are unprecedented in California water planning (See Volume 4 Reference Guide article by CWEMF, "Strategic Analysis Framework for Managing Water in California"). Fully implementing this work will take many years and significant resources. In the interim, qualitative approaches may be required for areas with insufficient data or inadequate tools to quantify all of the desired information.

The Planning Process

In a quantitative information approach, all of the quantitative information is intended to support a sound planning process that will lead to wise decisions about resource investments. As such, all analytical techniques should relate to one or more steps in the planning process. Typically, a formal planning process includes the following steps: identify problems, specify objectives, describe the relevant system, explore options, and make decisions (Box 4-5 The Planning Process). As planners explore options, they consider a range of ways to meet objectives. This step usually involves the most quantitative work and is further divided into three smaller steps: describe plausible changes, craft alternative responses, and compare performance.

DWR continues to provide ways to improve understanding of how the water management system works and how our water management actions interact with the environment. Chapter 3 California Water Today describes several aspects of the water management system as it has existed in recent years.

Box 4-5 The Planning Process

Typically, a formal planning process includes the following steps: identify problems, specify objectives, describe the relevant system, explore options, and make decisions. This planning process enhances understanding about the problem at hand and helps form a plan that is supported by those affected.

Identify Problems

What problem are we trying to solve? All stakeholders must agree on a clear statement of the problem before attempting to find a solution. Without agreement about the problem, the evaluation of possible solutions will be difficult or impossible. Problems may be existing conditions like too few returning salmon in a particular stream reach or challenges to future water management with a growing population.

Specify Objectives

What desirable performance characteristics are required to solve the problem? This is a crucial step in which stakeholders identify what the objectives are for solving the identified problem. Specifying objectives allows alternative plans to be developed that demonstrably address problems.

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Box 4-5 continued from previous page

Describe the Water Management System

What do we need to know to accomplish our objectives? This step in the planning process relates to the question, "How does the current water management system work now and how might it change?" Or asked differently, "What do we already know about the problem and potential solutions and how might the problem change in the future?" This is an area that will require continuous investigation and focused learning. Advancing scientific knowledge and using that knowledge effectively have been emphasized recently in the CALFED process and other planning efforts.

Explore Options

What are the implications of taking one action over another? This step in the planning process is where planners consider a range of possible means to meet the specified objectives. This step usually involves the most quantitative work. As a result, we have divided this step into three smaller steps: describe plausible changes, craft alternative responses, and compare performance. We will look at each one in succession.

Describe Plausible Changes

If we did not expect change to occur, we would not need to plan. If we were confident that our surroundings would stay the same and we were satisfied with the way things are, we could just maintain our current system. However, we recognize that change is occurring in our communities and in our world. Therefore, we have to predict what the future could be and how we can prepare for it.

Craft Alternative Responses

Having some idea of what is likely to happen in the future is necessary to plan for change. The other important piece of information is how the change will impact us if it does occur. If the change can cause a negative impact, we call this risk. If it can cause a positive impact, we call this reward. In simple terms, all of our planning is about balancing risk and reward. We want to avoid suffering a setback, or missing an opportunity for gain, as conditions change in the future. We all make these types of choices regularly in our personal lives. (For example, Should we buy life insurance or disability insurance? If yes, then how much should we buy and what type? When we save for our retirement, how much should we invest in stocks versus bonds versus real estate?)

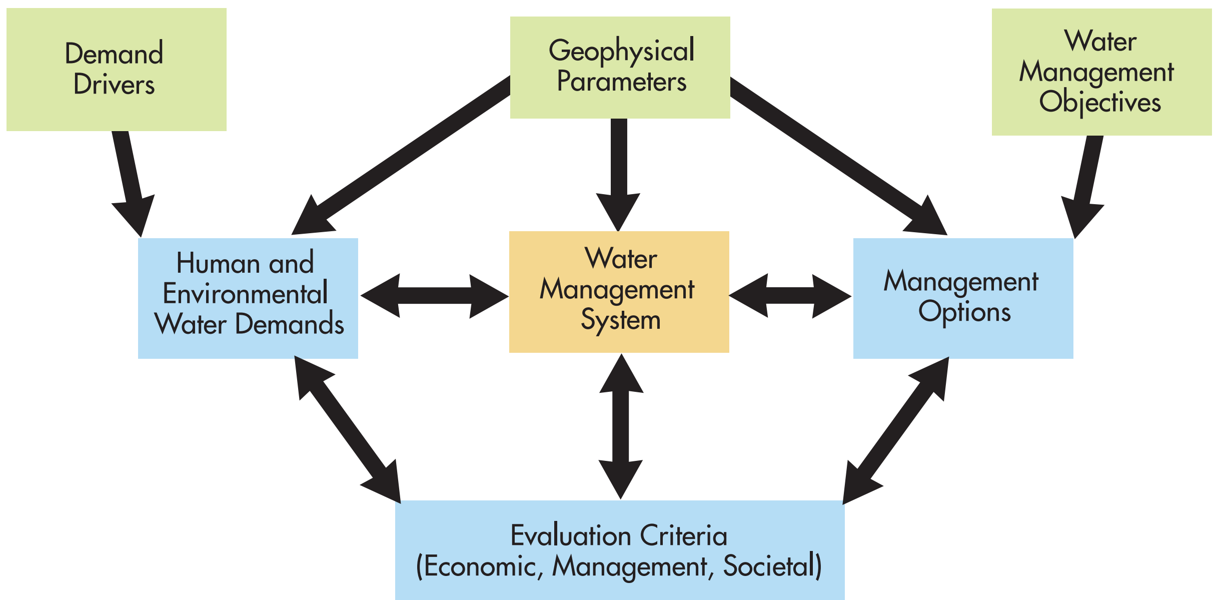
Compare Performance

Once we are clear about what changes we could face (future scenarios) and have assembled different combinations of promising management actions (response packages – mixes of resource management strategies) that could possibly meet our long-term objectives, we must try to predict how each of the alternative response packages will perform in a future that is uncertain. This comparison is usually attempted using some quantitative analyses.

Make Decisions

Choose one or more actions that appear to best satisfy the objectives. The goal of all planning is to make decisions that can be carried out to prepare for expected changes. Decisions regarding investments for water resource management will continue to be made in the political forums of public policy. However, if future water plan updates are successful, these decisions will be made in the context of a broader understanding of how the system works and what we can do to manage it successfully for the multiple objectives of California.

Figure 4-1 Conceptual framework diagram for analysis of water resources and management



DWR developed this conceptual diagram of the analytical framework to help promote common understanding of California's water management system. The diagram shows the management system (orange box), factors that can change (blue boxes), and factors held constant (green boxes) for each analytical study.

The waterflow diagrams in Volume 3 provide a useful view of how the parts of the system work. DWR has also developed a high-level conceptual framework as a basis to identify, document, and describe interactions and promote common understanding (see Figure 4-1 Conceptual framework diagram for analysis of water resources and management and Box 4-6 Conceptual Framework Diagram and Description). DWR plans to work closely with the advisory committee and other interested experts as we document what observable data and causal relationships are used for future analyses.

As we explore our options, we must describe plausible changes. When it comes to water, many things can change and affect our ability to provide the benefits that are important to our society. Some of the most important areas for change are described in the section "Changes to Consider When Preparing for the Future" later in this chapter. When considering the future, we know our predictions will never be completely accurate. Nonetheless, we rely on predictions about the future during our daily lives (for example, weather forecasts, expected commute times, investment appreciation, etc.). We recognize that uncertainty exists in all predictions, so we consider that uncertainty, along with other factors, when deciding how to use the information. The new approach in Update 2005 explicitly addresses these uncertainties.

We typically craft responses based on what we expect to change, the likelihood of that change occurring, and the risk we face if the change occurs and we are not prepared. Water managers must routinely decide how many resources to spend today to protect against future uncertainties, especially extreme events like multiple dry years. There are often multiple responses available to satisfy a given objective, so it is prudent to consider several alternatives to find responses that balance costs, benefits, and tradeoffs effectively and efficiently. Volume 2 describes 25 resource management strategies that planners have available to them when designing a response to the changes they are facing and may face.

Partial Application of Scenario Approach

The introduction of scenarios is a major difference between the approach used in previous updates and the new approach. The goal is to compare and contrast performance of possible management responses against plausible future conditions. As used in *California Water Plan Update 2005*, scenarios represent

Box 4-6 Conceptual Framework Diagram and Description

Demand Drivers. Factors that influence the calculation of water demands, which are not directly controlled by water management activities. For example, population, population density, land use patterns, and economic activity.

Geophysical Parameters. Factors that represent the basic hydrology, hydrogeology, geology, and climate, which form the natural constraints of the system. For example, precipitation, soil properties, and aquifer transmissivity.

Water Management Objectives. Objectives developed by policymakers for desired outcomes of the water management system while considering the various constraints, competing demands, and resource strategies. For example, desired water quality and desired water reliability at a particular location and time and for a particular use.

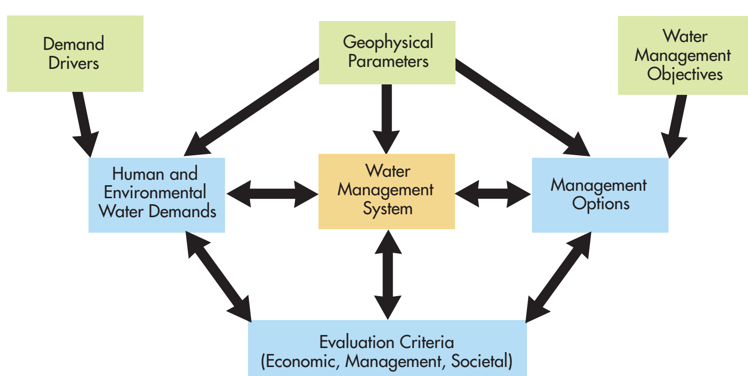
Human and Environmental Water Demands. Dynamic consumptive and nonconsumptive demands for water that fluctuate based on the climate, economy, changes in water use efficiency, population growth, and other factors. Consumptive demands include activities that deplete water from the water management system by evaporation, evapotranspiration, or flows to saline water bodies. Nonconsumptive demands include activities that require a specific quantity of water at a particular location and time, but do not deplete from the water management system. This includes releasing water for hydropower production, instream flows, or municipal water use that flows to a wastewater treatment facility and is later released to a stream or recharged to groundwater.

Management Options. Management options are the numerous resource strategies available to water managers to improve operation of the water management system and are heavily influenced by the desired water management objectives. This includes actions like water use efficiency, surface or groundwater storage, floodplain management, and ecosystem restoration.

Evaluation Criteria. Factors that serve as dynamic evaluation criteria to guide policymakers, water managers, and the public about how well a particular hypothetical scenario and operation of the water management system is at meeting water management objectives. This includes things like economic cost of implementing different resource strategies, environmental benefits, water reliability, and improvements in water quality.

Water Management System. The system of man made and natural water storage and conveyance features where the water management decisions are implemented. This includes location, storage and flow capacities, and operating criteria of reservoirs, canals, wetlands, floodplains, lakes, rivers, and groundwater basins.

Figure 4-1 Conceptual framework diagram for analysis of water resources and management



DWR developed this conceptual diagram of the analytical framework to help promote common understanding of California's water management system. The diagram shows the management system (orange box), factors that can change (blue boxes), and factors held constant (green boxes) for each analytical study.

baseline conditions that we could reasonably expect to face in the year 2030, based on what we know to be true today. DWR has developed three scenarios, each describing a different baseline for 2030. These scenarios are possible pictures of the future that depend on many assumptions. They are not predictions and do not include new water agency-sponsored conservation programs or climate change effects. The water community would use each scenario to compare the performance of possible management responses. Having multiple future scenarios can help identify management responses that perform well when compared across a wide array of baseline conditions that could occur in the future.

The scenarios presented in update 2005 are only part of the story of California's water future. The scenarios represent different baseline conditions for 2030 that could affect water demands and supplies, but that the water community has little or no control over. The other part of the story is the alternative management strategies (called response packages in Update 2005) that still need to be considered to prepare for the potential changes described in the scenarios. The next California water plan update will present quantitative information on the whole story—the baseline conditions water managers may face and the alternative strategies needed to address these conditions.

Baseline Scenarios to Describe Future Conditions

Although multiple future scenarios will be used in the quantitative work for the next California water plan update, DWR has not yet developed the analytical tools to quantify both scenarios and response packages. Three baseline scenarios in this section demonstrate how scenarios can be used to better understand the implications of future conditions on water management decisions. These scenarios are referred to as baseline because they represent changes that are reasonably likely to occur without additional management intervention beyond those currently planned. The narrative descriptions of these scenarios were developed by water plan staff and the advisory committee.

Previous water plan updates based planning assumptions on a single likely future condition. The use of multiple future scenarios provides decision-makers, water managers, and planners much more information about what they might expect in the future and how different management actions might perform across a range of possible futures. The scenarios are created by varying important assumptions about water and other resource conditions in order to highlight important categories of uncertainties.

These scenarios are referred to as baseline because they represent changes that are reasonably likely to occur without additional management intervention beyond those currently planned.

The primary reason to use multiple scenarios is that different assumptions about the future can significantly affect the nature and outcome of various mixes of management strategies. Some management strategies may be effective and economical regardless of the future scenario. Other strategies may only be suited if specific conditions develop in the future.

Developing quantitative estimates of water demands and supplies for multiple future scenarios and management responses requires using available data and assumed relationships. DWR and stakeholders considered numerous factors that could vary in the future and developed three preliminary narrative future scenarios that can be used to begin the analysis for the next California water plan update. However, DWR and stakeholders may develop other scenarios as work progresses.

Table 4-1 (Scenario factors affecting regional and statewide water demands and supplies) shows factors that were considered in developing the scenario narratives. These factors may vary across scenarios, and each factor must be quantified. The availability and resolution of data vary widely. Key factors have been identified, but much work remains before reaching agreement on the relationships between the factors and the methods that will be used to quantify them.

As work moves forward on the next California water plan update, DWR and stakeholders may add or eliminate factors to help answer questions about future scenarios. Although all the factors in Table 4-1 are needed to define the strategies, DWR began analysis by varying only the factors primarily related to land and water use patterns over which the water community has little control (those listed in the upper portion of Table 4-1). Other factors also may be varied to help us gain insight into specific questions. Following are brief descriptions of each example scenario.

Three Baseline Scenarios for 2030

This section describes some of the key assumptions used to develop the following three baseline scenarios for 2030.

- Scenario 1—**Current Trends.** Recent trends continue for the following: population growth and development patterns, agricultural and industrial production, environmental water dedication, and naturally occurring conservation

Table 4-1 Scenario factors affecting regional and statewide water demands and supplies

FACTOR [1]	SCENARIO 1 CURRENT TRENDS	SCENARIO 2 LESS RESOURCE INTENSIVE	SCENARIO 3 MORE RESOURCE INTENSIVE
Total Population	DOF	DOF	Higher than DOF
Population Density	DOF	Higher than DOF	Lower than DOF
Population Distribution	DOF	DOF	Higher Inland & Southern; Lower Coastal & Northern
Total Commercial Activity	Current Trend	Increase in Trend	Increase in Trend (Same as Scenario 2)
Commercial Activity Mix	Current Trend	Decrease in High Water Using Activities	Increase in High Water Using Activities
Total Industrial Activity	Current Trend	Increase in Trend	(Same as Scenario 2) Increase in Trend
Industrial Activity Mix	Current Trend	Decrease in High Water Using Activities	Increase in High Water Using Activities
Irrigated Crop Area (Includes Irrigated Land Area and Multi-cropped area)	Current Trend	Level Out at Current Crop Area	Level Out at Current Crop Area
Crop Unit Water Use	Current Trend	Decrease in Crop Unit Water Use	Increase in Crop Unit Water Use
Environmental Water-Flow Based	Current Trend	High Environmental Protection	Year 2000 Level of Use
Environmental Water-Land Based	Current Trend	High Environmental Protection	Year 2000 Level of Use
Naturally Occurring Conservation[2]	NOC Trend in MOUs	Higher than NOC Trend in MOUs	Lower Than NOC Trend in MOUs
Urban Water Use Efficiency	All Cost Effective BMP's in Existing MOU's Implemented by Current Signatories (present commitments)		
Ag Water Use Efficiency	All Cost Effective EWMP's in Existing MOU's Implemented by Current Signatories (present commitments)		
Per Capita Income	Current Trends		
Ratio of Seasonal to Permanent Crop Mix	Current Trends		
Irrigated Land Retirement	Currently Planned		
Hydrology	Essentially a Repeat of History		
Climate Change	Essentially a Repeat of History		
Colorado River Supply	Equal to 4.4 Plan		
Existing Inter-Regional Import Projects	Current Conditions		
Flood Management	Current capacities, management practices and operations		
Energy Costs	As Projected From Current Trends		
Ambient Water Quality	Current Conditions		
Drinking Water Standards	Current and Planned		
Ag Discharge Requirements	Current and Planned		
Urban Runoff Mgmt.	Current Level of Use		
Recreation	Present Demand Trends Continued		
Desalting	Current Level + Permitted/Financed		
Recycled Water	Current Level + Permitted/Financed		
Water Transfers Within Regions	Currently Approved Transfers		
Water Transfers Between Regions	Currently Approved Transfers		
Conjunctive Use and Groundwater Management	Current Level + Permitted/Financed		
Surface Water Storage	Current Level + Permitted/Financed		
Conveyance Facilities	Current Level + Permitted/Financed		
Rate Structure	Current Practices - pricing constrained to cost reovery		

(1) Factors should be considered as an initial list that will be modified, as needed, as analyses proceed for next Water Plan Update.

(2) Naturally Occurring Conservation is the amount of background conservation (changes in plumbing codes, etc.) occurring independently from the BMP and EWMP programs.

(like plumbing code changes, natural replacement, actions water users implement on their own, etc.).

- Scenario 2—**Less Resource Intensive.** Recent trends for population growth, higher agricultural and industrial production, more environmental water dedication, and higher naturally occurring conservation than Current Trends (but less than full implementation of all cost-effective conservation measures currently available).
- Scenario 3—**More Resource Intensive.** Higher population growth rate, higher agricultural and industrial production, no additional environmental water dedication (year 2000 level), and lower naturally occurring conservation than Current Trends.

All three scenarios include assumptions for two kinds of water use efficiency actions: (1) those that water users take on their own (called naturally occurring conservation) and (2) those encouraged by water agency programs, policies, and requirements. Only naturally occurring conservation was varied among the scenarios; and all scenarios include the same continued implementation of cost-effective actions by water agencies.

Scenario 1: Current Trends

- Population and Land Use: The population of California meets Department of Finance (DOF) estimates of 48.1 million in 2030 with increasing population pressure in the Central Valley and on the coast. Expanding metropolitan areas continue to dominate urban growth.
- Commercial and Industrial: Driven to reduce costs in the face of competition, industry becomes more efficient in water use. Due to cost efficiencies, businesses have been reducing water use over time, primarily by replacing old or broken-down equipment with high-efficiency machines.
- Agriculture: Farmers are increasingly using sprinklers and drip irrigation, moving away from flooding and furrows. Farmers produce more "crop per drop" through a variety of means, including changes in irrigation methods, although more improvement is possible. Increased cost of land is shrinking agricultural land availability. Irrigated crop area (including multicropping) is slightly less than in 2000. Multicropping area increases significantly from the 2000 level.
- Environment: Environmental flows reach half way to the levels needed to meet the objectives of CALFED's Ecosystem Restoration Program and the objectives in the Anadromous Fisheries Restoration Program. Water dedicated to wet lands reaches half way to "Level 4" supplemental water supplies for National Wildlife Refuges cited in Central Valley Project Improvement Act (CVPIA) sections 3405 and 3406(b). Urban development continues to encroach on functioning floodplains in some areas.
- Naturally Occurring Conservation: The background conservation that will occur as a result of emerging conditions (ongoing changes in plumbing codes, etc.) results in some increase in efficiency in all sectors.
- Other Factors: Other factors remain unchanged (see Table 4-1 Scenario factors affecting regional and statewide water demands and supplies).

Scenario 2: Less Resource Intensive

- Population and Land Use: Population in 2030 is 48.1 million. Californians live in mixed use developments with native vegetation requiring little or no irrigation. An increase in population density means infill in existing urban areas and less development of new urban land. This compact development has reduced impervious surfaces, which benefits open space, reduces runoff, increases groundwater recharge, and affects other related issues. The cost of land is shrinking the availability of housing in Southern California.
- Commercial and Industrial: Due to market conditions, industry has shifted from water-intensive processing to dry product assembly, reducing water use. Businesses have dramatically reduced water demand and have moved to machines with high-efficiency water use to accomplish standard tasks. Potential financial gains have accelerated the move to machines with high-efficiency water use to accomplish standard tasks. Urban areas have a high degree of commercial and industrial productivity. Also, California has emerged as a leading industrial producer of environmental products and continues as a force in producing hardware for the technology industry.
- Agriculture: Irrigated crop area is at the same level as in 2000. Land area removed from agriculture must be replaced by a combination of new land coming into production and increased multicropping. Improved water management is increasing water efficiency. A healthy, efficient agricultural sector produces more per acre and decreases applied water per irrigated crop acre.
- Environment: Projects are designed to achieve multiple benefits integrating ecosystem restoration with water supply reliability. Management actions are oriented toward the sustainability, restoration, and improvement of the natural infrastructure. Water dedicated to instream use and aquatic life enhancement is yielding increased populations. Environmental flows reach the levels needed to meet the objectives of CALFED's Ecosystem Restoration Program and the objectives in the Anadromous Fisheries Restoration Program. Water dedicated to wetlands reach

the "Level 4" supplemental water supplies for National Wildlife Refuges cited in CVPIA sections 3405 and 3406(b).

- Naturally Occurring Conservation: The background conservation that will occur as a result of emerging conditions is higher in the agricultural and urban sectors than under Scenario 1. Business and agriculture apply efficiency measures for reasons other than reducing water demand or water-related costs. Current plumbing codes and other existing policies have increased efficiency greater than in scenarios 1 and 3.
- Other Factors: Other factors remain unchanged from Scenario 1.

Scenario 3: More Resource Intensive

- Population and Land Use: Population in 2030 is 52.3 million and is dispersed regionally. Expanding urban areas are commonplace. The Central Valley is experiencing air and water quality problems due to the stress of the large population. The population is more widely distributed, resulting in more outdoor residential water use (for example, larger residential lot size). Individuals tend to drive long distances to the workplace.
- Commercial and Industrial: California has emerged as a leading industrial producer of environmental products and continues as a force in producing hardware for the technology industry. California's leadership in high tech hardware places constraints on its water resources because this industry is a high water user that has not advanced efficiency technology to limit its water use. The industry continues to rely on high water-using processes based on market conditions.
- Agriculture: Irrigated crop area is at the same level as in 2000. The healthy agricultural sector maintains past levels of food and fiber production. Low-density urban development expands onto prime farmland, but harvested acreage remains about the same due to increased multicropping and new lands coming into production. The annual volume of applied water per crop is high due to the changing nature of crops and the movement of agricultural production to lands with poorer soil quality.
- Environment: Environmental flows remain at year 2000 levels. Thus, the flow objectives of CALFED's Ecosystem Restoration Program and the Anadromous Fisheries Restoration Program remain unmet. Water dedicated to wetlands remain at year 2000 levels, and the "Level 4" supplemental water supplies for National Wildlife Refuges cited in CVPIA sections 3405 and 3406(b) are not achieved. Californians recognize the link between the environment and their health and personal well being, but there is less water made available to accomplish environmental objectives.
- Naturally Occurring Conservation: The background conservation that will occur as a result of emerging conditions in the agricultural and commercial and industrial sectors is lower than current trends.
- Other Factors: Other factors remain unchanged from scenarios 1 and 2.

Preliminary Water Demand Estimates for the Baseline Scenarios

Numerical estimates of water demand[1] for the three baseline scenarios are drawn from an informal collaborative study by DWR staff and a graduate student from the Pardee RAND Graduate School (hereafter, Groves, Matyac, and Hawkins (2005)). A detailed description of the methods used, results, and implications can be found in the Volume 4 Reference Guide article "Quantified Scenarios of 2030 California Water Demand."

Groves, Matyac, and Hawkins (2005) created a basic scenario water demand estimator (demand estimator) to quantify the water demands for the three narrative scenarios of 2030 described previously. Scenario water demand estimates were made individually for the urban, agricultural, and environmental sectors for each of the 10 California hydrologic regions. A unique set of input values was assigned for each scenario to reflect the qualitative narrative descriptions and scenario factors in Table 4-1 (Scenario factors affecting regional and statewide water demands and supplies). The demand estimator was run using visual programming software to assist collaboration between analysts, decision-makers, and stakeholders.

Future urban water demand was estimated individually for the residential, commercial, industrial, and public sectors. The demand for each urban sector was estimated by simulating plausible growth patterns in demand units such as houses, employees, and persons. The number of future demand units was then combined with estimates of plausible values for 2030 water demand per unit. The demand estimator includes factors that account for how changes in water price, personal

[1] During the preparation of Update 2005, many discussions occurred on how to describe what has traditionally been called water "demands." A primary concern is that "demand" is not static. In economic terms, a person's desire to use water is said to be elastic, that is, based on a number of factors such as the intended use for the water, the price of water, and the cost of alternative ways to meet the intended use. As used in this section, the word "demand" technically means, "the desired quantity of water that would be used if the water is available and a number of other factors such as price do not change."

Table 4-2 Scenario factors affecting urban water demand

Urban demand drivers (in millions)	Year 2000	Year 2030 scenarios		
		Current Trends	Less Resource Intensive	More Resource Intensive
Population	34.1	48.1	48.1	52.3
Coastal & northern	8.3	10.8	10.8	11.2
Inland & southern	25.8	37.3	37.3	41.1
SF houses	7.5	11.0	8.9	12.7
MF houses	4.1	5.6	7.0	5.1
Commercial employees	16.3	24.8	25.9	28.0
Industrial employees	3.5	4.0	4.1	4.5

Note: Numbers in millions
SF = single family
MF = multifamily

income, naturally occurring conservation, and the continuation of existing water use efficiency programs influence future per unit water demand values.

Agricultural water demand was estimated in similar fashion. Plausible projections of the number of irrigated acres by crop type and hydrologic region were combined with plausible values of per-acre crop water demand in 2030. Some factors describe how future acreage is influenced by changing land use, cropping patterns, and multicropping as well as how per-acre crop water demand responds to changes in irrigation method, improvements in irrigation technology, and water price.

Environmental water demand for each 2030 scenario was assumed to equal water dedicated to the environment in 2000 (an average water year) plus an additional scenario-specific amount. The authors based additional environmental allocations on a preliminary assessment by Environmental Defense of unmet environmental flow objectives (see Volume 4 Reference Guide article "Recommendations Regarding Scenarios and Application of Environmental Water 'Demands' in the State Water Plan Update & Quantification of Unmet Environmental Objectives in State Water Plan 2003 Using Actual Flow Data for 1998, 2000, and 2001"). These unmet objectives include the additional instream flows needed to meet the goals of CALFED's Ecosystem Restoration Program in an average water year, the objectives in the Anadromous Fisheries Restoration Program, and the additional water needed to reach the "Level 4" supplemental water supplies for National Wildlife Refuges cited in CVPIA sections 3405 and 3406(b).

Scenario Factors Affecting Water Demand

Values for the major factors that affect urban demand and are used in the demand estimator are reported in Table 4-2 (Scenario factors affecting urban water demand) for 2000 and 2030 under each of the three baseline scenarios. All three scenarios show large increases in population, housing, and number of employees. The 2030 housing stock reflects a significantly greater proportion of multifamily units in Less Resource Intensive (Scenario 2) and more single-family units in More Resource Intensive (Scenario 3), as compared to Current Trends (Scenario 1). The number of employees in the commercial and industrial sectors is greatest in the More Resource Intensive scenario.

For the agricultural sector, the irrigated crop area (including multicropping) decreases about 5 percent from 2000 to 2030 in the Current Trends scenario and remains the same as year 2000 in the Less Resource Intensive and More Resource Intensive scenarios (see Table 4-3 Scenario factors affecting agricultural water demand). Irrigated land area, the "footprint" of irrigated agriculture, decreases by 5 percent in the Less Resource Intensive scenario and by 10 percent under both the Current Trends and More Resource Intensive scenarios. Greater multicropping compensates the reduced irrigated land area, especially in the More Resource Intensive scenario.

The additional instream flows and water for managed wetlands used to set scenario environmental water demands are shown in Table 4-4 (Year 2000 unmet environmental water objectives, See Volume 4 Article by Environmental Defense, "Recommendations Regarding Scenarios and Application of Environmental Water

Table 4-3 Scenario factors affecting agricultural water demand				
Ag. demand drivers (area in millions of acres)		Year 2030 scenarios		
	Year 2000	Current Trends	Less Resource Intensive	More Resource Intensive
Irrigated crop area	9.51	9.05	9.52	9.50
Irrigated land area	8.98	8.08	8.53	8.08
Multicropped area	0.54	0.97	0.99	1.42

Table 4-4 Year 2000 unmet environmental water objectives	
Location	Unmet flow objective (taf)
Trinity River (Lewiston)	344
American River (Nimbus)	55
San Joaquin River (Vernalis, DAYFLOW)	96
San Joaquin River (Below Friant)	268
Stanislaus River (Goodwin)	34
Ecosystem Restoration Program #2 Flow Objective	65
Level 4 Refuge Water [a]	125
Total per year	*987*

taf = thousand acre-feet
a. Annual water needed in addition to current deliveries to 19 Sacramento and San Joaquin refuges

'Demands' in the State Water Plan Update & Quantification of Unmet Environmental Objectives in State Water Plan 2003 using actual flow data for 1998, 2000, and 2001"). In the Current Trends scenario, half of these additional flows are added to year 2000 environmental water use for 2030 environmental water demand; 100 percent of the flows are added in the Less Resource Intensive scenario; and no additional flows are added to 2000 use in the More Resource Intensive scenario. For this analysis, additional instream flows were assigned to hydrologic regions by river reach, and "Level 4" refuge water was distributed evenly between the Sacramento and San Joaquin River regions.

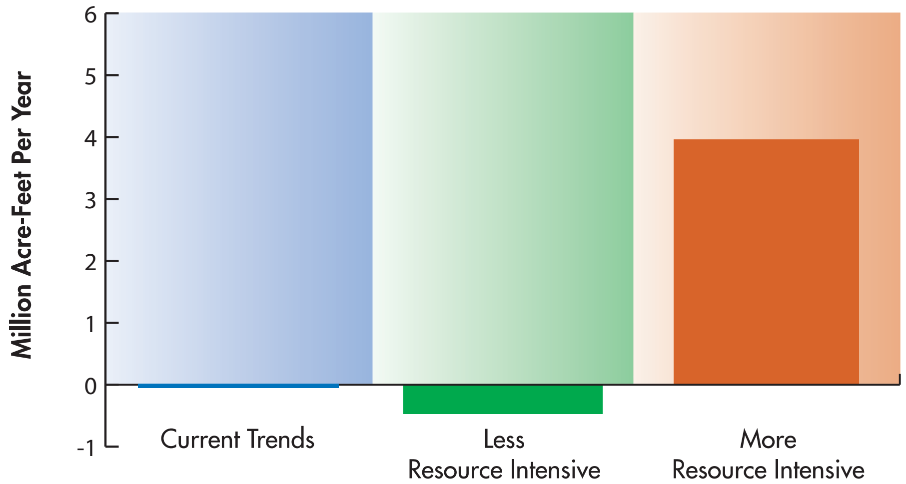
Scenario Water Demand Changes between 2000 and 2030

The combined (or net) change in scenario water demands for average water years is shown in Figure 4-2 (Net changes statewide in average-year water demand for baseline scenarios, 2000–2030). **For all three scenarios, an additional 1 million to 2 million acre-feet per year of water will be needed by 2030 to stop groundwater overdraft statewide** (DWR Bulletin 118 Update 2003).

As shown in Figure 4-2, for the three baseline scenarios, statewide change in average-year water demand ranges from a reduction of about 0.47 million acre feet per year to an increase of 4.0 million acre-feet per year. The magnitude of this range reflects the differences in assumptions used for the three scenarios. Total statewide water demand decreases only slightly under the Current Trends scenario, a pattern that may be surprising given projected population growth. The reason for this is revealed when we consider the components of net demand, namely statewide changes in urban, agricultural, and environmental demand for each of the three scenarios as shown in Figure 4-3 (Net changes statewide in average-year water demand for baseline scenarios by sector, 2000–2030). **The estimated slight decrease in total statewide water demand under the Current Trends scenario illustrates that California water issues are primarily regional in nature and that inappropriate use of statewide averages can mask significant issues.**

While instructive, these preliminary estimates cannot be used as indicators of potential future shortages because they describe the additional water demands California could face

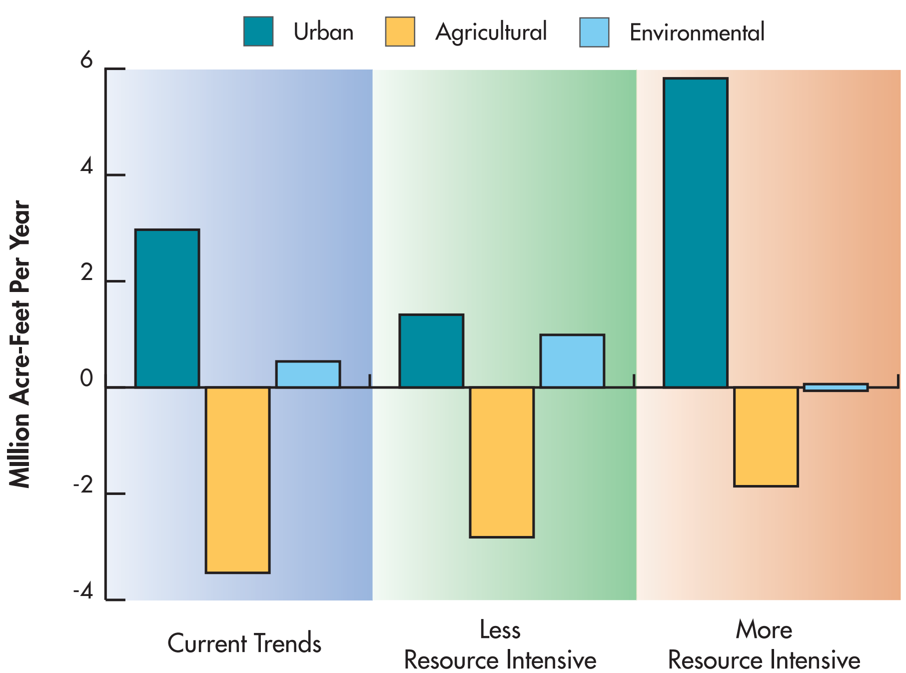
Figure 4-2 Net changes statewide in average-year water demand for baseline scenarios, 2000–2030



An additional 1 maf to 2 maf per year (not shown in the figure) is needed for all scenarios to eliminate ground-water overdraft statewide.

Water demands may change between 2000 and 2030 for average water conditions. Statewide water demand changes are shown for three baseline scenarios.

Figure 4-3 Net changes statewide in average-year water demand for baseline scenarios by sector, 2000–2030



An additional 1 maf to 2 maf per year (not shown in the figure) is needed for all scenarios to eliminate groundwater overdraft statewide.

Water demands may change between 2000 and 2030 for average water conditions. Water demand changes are shown by water use sector statewide for three baseline scenarios.

in 2030 without additional demand management beyond current policies, and because they do not consider the future capability of the water management system to meet these demands under different hydrologic conditions.

Under all three scenarios, urban water demand increased between year 2000 and 2030 because of population growth. In the Current Trends and Less Resource Intensive scenarios, demand for environmental water was larger in 2030 but stayed the same as year 2000 in the More Resource Intensive scenario, consistent with the Table 4-1 (Scenario factors affecting regional and statewide water demands and supplies).

Agricultural water demand decreased by 2030 under all three scenarios. In the case of the Current Trends scenario, agricultural water demand decreased due to an assumed 5 percent decline in irrigated crop area (primarily because of urbanization), as well as a 5.6 percent reduction in crop unit water use—the irrigation water applied per unit of crop area—due to increased water use efficiency. Under the Less Resource Intensive and More Resource Intensive scenarios, irrigated crop area was kept the same as year 2000, but agricultural water demand was lower than 2000 because the crop unit water use was reduced by 8.3 percent and 5.3 percent, respectively.

The decrease in agricultural water demand was greater than the increase in urban and environmental water demand in the Current Trends and Less Resource Intensive scenarios. In the More Resource Intensive scenario, increases in urban water demand significantly outweighed demand reductions in the agricultural sector.

Potential transformations in statewide water demand patterns are further illustrated by examining the net water demand changes separated out by hydrologic regions as shown in Figures 4-4 (Net changes in average-year water demand for baseline scenarios by region, 2000–2030) and Figure 4-5 (Percent change in average-year water demand for baseline scenarios by region, 2000–2030). These charts shows that future changes in water demand will likely vary substantially by region and scenario.

Implications from Preliminary Analysis

It is important to note that estimates of future statewide average-year water demands, however small or large, do not adequately characterize the challenges facing California water. Increases in water demand must be addressed at regional and local scales because available supplies in one part of the state cannot necessarily be used to meet rising demands in another part. As local demands increase, future droughts could result in more severe local water shortages than in recent experience. Moreover, the challenges of eliminating groundwater overdraft, flood management, water quality protection, and water systems management to help restore the environment all require that California's water managers develop strong water plans that go well beyond just meeting water demand increases in average years.

The greater urban water demand predicted under all three plausible scenarios would present significant challenges to water planners. If future factors influencing water demand resemble the Current Trends scenario, we would need to offset an additional 3.5 million acre-feet of urban and environmental water demand per year with a combination of management strategies to reduce demand, improve system efficiency, and redistribute and augment supplies[2]. Although there may be commensurate reductions in the agriculture sector, much of this demand reduction would occur in the Central Valley; whereas, much of the additional urban demand would be in the southern part of the state. The ability to transfer water from the Central Valley to Southern California could be constrained by existing conveyance facilities, area-of-origin issues, environmental impacts, and other third-party effects. This fact underscores the need for strong integrated regional water management plans supported by strong statewide water management systems.

If future factors influencing water demand resemble the More Resource Intensive scenario, water management challenges would be even greater. Demand would increase in all areas of California; the demand to grow more crops for food and fiber would be greater than in the other two scenarios. Consequently, any reduction in agricultural demand would offset only a portion of the increase in urban demand.

The demand changes predicted in the Less Resource Intensive scenario would be more manageable than those for the other two scenarios. If, however, future water supplies are lower because of climate change, for example, then even this scenario could present considerable challenges for California water management. To help meet these challenges, DWR plans to work with

[2] Volume 2 describes 25 resource management strategies that can be combined in various ways to meet the water management objectives and goals of different regions and to achieve multiple benefits.

regional and local partners to develop the necessary data and analytical tools for of the next California water plan update. These will provide a more comprehensive evaluation of a variety of management responses for a number of plausible scenarios. DWR will quantify water demands and supplies for each of the future scenarios as part of the phased work plan of this and the next California water plan update.

Increases in water demand must be addressed at regional and local scales because available supplies in one part of the state cannot necessarily be used to meet rising demands in another part.

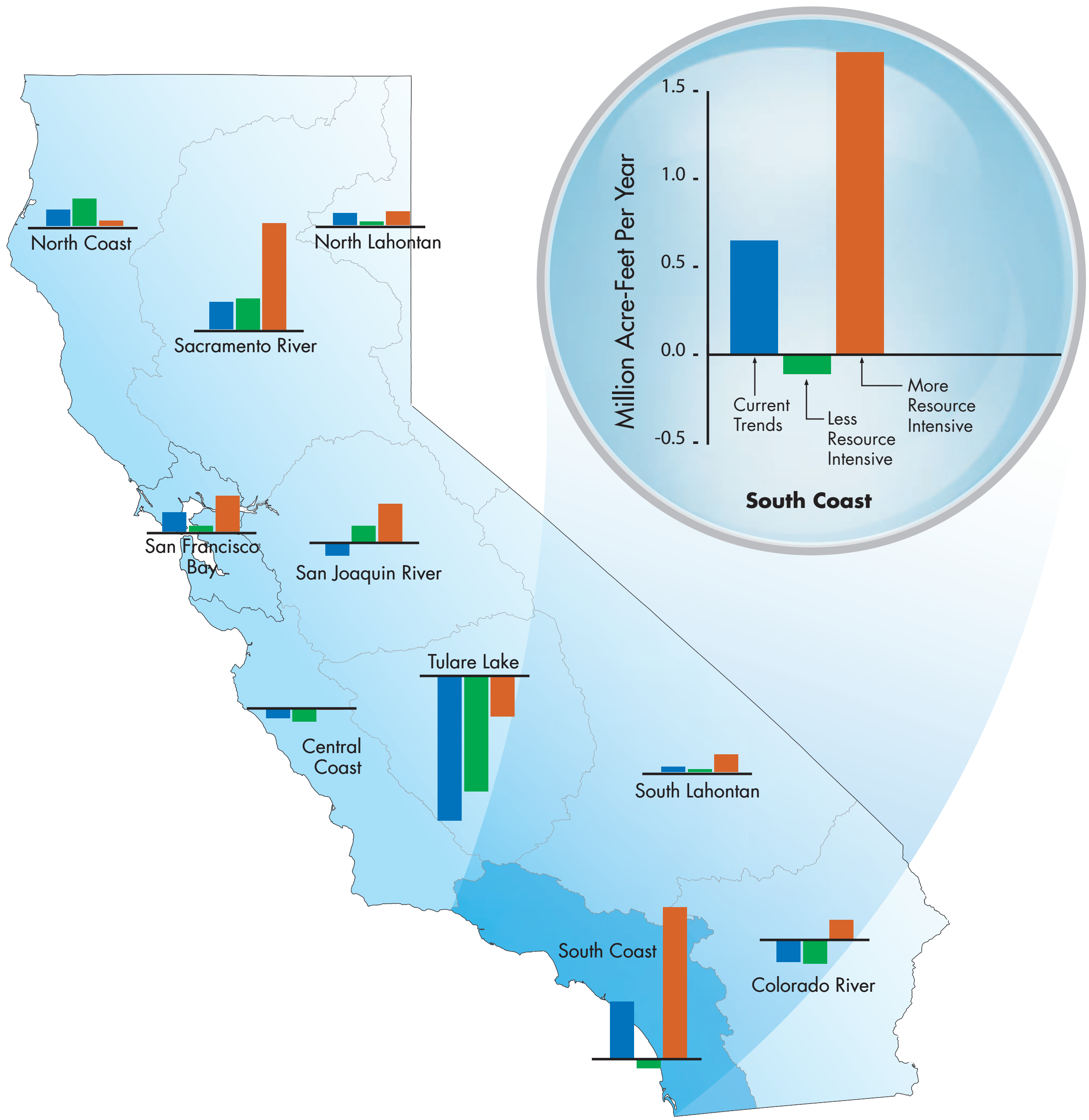
These preliminary estimates of water demand by baseline scenario (derived from Groves, Matyac, and Hawkins (2005)) illustrate how water demands can change over the next 25 years based on different assumptions about key factors that influence water demand. These results show that statewide demand can vary significantly and that demand can vary significantly across regions and across water use sectors. Although instructive, these preliminary estimates cannot be used as indicators of potential future shortages. They describe what additional water demands California may face in 2030, but without additional demand management beyond current policies. Further, they do not consider the future capability of the water management system to meet these demands under different hydrologic conditions. In order to assess how balanced the overall water management

Box 4-7 Crafting Sample Response Packages

The scenarios in California Water Plan Update 2005 represent different baseline conditions for 2030 that could affect water demands and supplies, but that the water community has little or no control over. In the next California water plan update, each future scenario will be used to test a number of different response packages, that is, different mixes of resource management strategies (see Volume 2 for discussion of 25 resource management strategies). Individual members of the Water Plan Advisory Committee have begun using the baseline scenarios and resource management strategies described in Update 2005 to develop two independent examples of how baseline scenarios can be extended to include a mix of management strategies or response packages. These examples include:

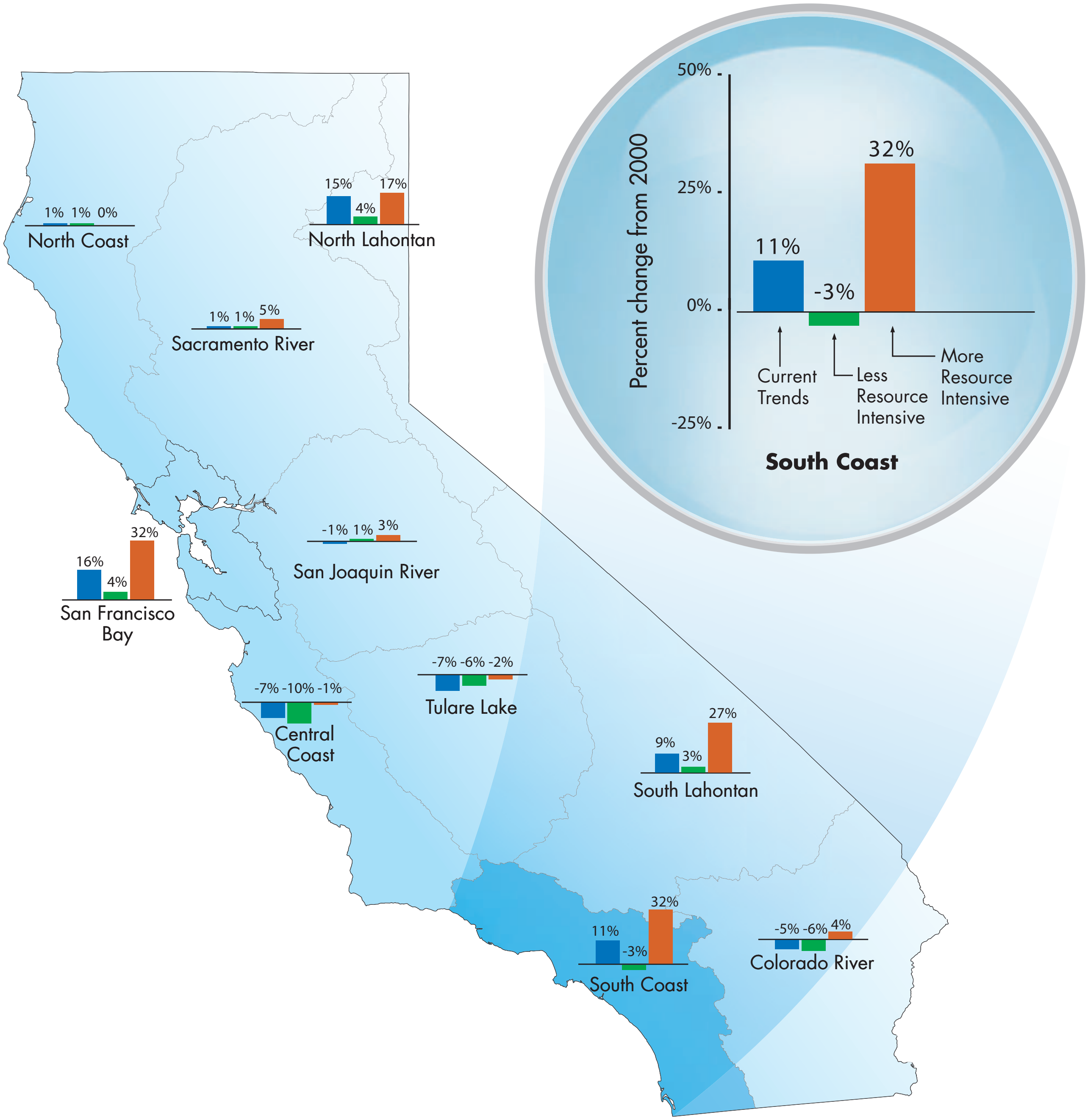
- An aggressive water use efficiency response package is presented in the publication by the Pacific Institute, "California Water 2030: An Efficient Future" (See www.pacinst.org/). The Pacific Institute High Efficiency response package is based on widespread adoption of existing water-efficiency technologies, not on the invention of new efficiency options, and on different estimates of water prices and trends. The Pacific Institute's High Efficiency response package estimated 2030 urban and agricultural water demands by (1) using the California Water Demand Scenario Generator (analytical tool) developed for Water Plan Update 2005, (2) adopting the same assumptions for population, housing distribution, agricultural land area, crop type and distribution, and income projections used in the water plan's Current Trends baseline scenario, (3) using different assumptions for urban and agricultural water price trends, and (4) including additional water use efficiency measures that have been shown to be achievable and cost-effective using existing technology (Mayer et al. 1999, Gleick et al. 2003). In the report, the High Efficiency response package is compared with the Water Plan Current Trends baseline scenario.
- In 2005, the Bren School at UC Santa Barbara and the RAND Corporation began collaborating to explore alternative response packages for the Southern California hydrologic region to assess the potential of increasing reliance on local water supplies and demand reduction. Using an enhanced version of the California Water Demand Scenario Generator developed for Water Plan Update 2005, this team is evaluating the performance of alternative response packages consisting of urban water use efficiency, conjunctive use and groundwater storage, and recycled municipal water, for multiple future conditions (see Volume 4 article, "Quantified Scenarios of 2030 California Water Demand"). The analytical tool and results will be used in a series of workshops with stakeholders and decision-makers in Southern California during the winter of 2005-06. For more information, see the Web sites of the Bren School's Water Policy Program (www.bren.ucsb.edu/academics/WaterPolicyProgram.htm) and the RAND Corporation's program on Improving Decisions in a Complex and Changing World (www.rand.org/ise/projects/improvingdecisions/).

Figure 4-4 Net changes in average-year water demand for baseline scenarios by region, 2000–2030



Water demand changes are shown in the 10 hydrologic regions for three baseline scenarios. South Coast region demands are magnified to show volumetric changes in million acre-feet per year, which can be either lower (negative bar) or higher (positive bar) than year 2000 water uses in the region. An additional 1 maf to 2 maf per year (not shown in the figure) is needed for all scenarios to eliminate groundwater overdraft statewide.

Figure 4-5 Percent change in average-year water demand for baseline scenarios by region, 2000-2030



Regional water demand changes in Figure 4-4 are presented as a percentage of the total water use in the region in year 2000. The South Coast region shows relative water demand changes in percent per year, which can be either lower (negative bar) or higher (positive bar) than uses in 2000.

system will be in 2030, after estimating possible demand, we must still incorporate supply conditions, craft alternative responses, and then compare performance of the response packages under each scenario (see Box 4-5 The Planning Proess). More refined estimates of future demand will be done as part of the next California water plan update along with a comparison of performance between specific noteworthy response packages.

Next Steps – Craft Responses and Compare Performance

In the next California water plan update, each baseline scenario will be used to test a number of different regional response packages, that is, different mixes of resource management strategies (see Volume 2 for discussion of 25 resource management strategies). Comparing the performance of different response packages will provide useful information to decision-makers and water managers that must choose actions to help achieve a desirable future condition. Stakeholders can identify areas of agreement and where short-term resource management strategies can work well regardless of the future conditions. In a long-term time frame, where uncertainties about future assumptions increase, plans can be revised to include resource management strategies that can better respond to the changed conditions.

Response packages can be modified and should be used as a basis for identifying short-, medium-, and long-term actions of a plan. DWR will work with stakeholders and other interested parties to develop several response packages on a regional basis during the preparation of the next California water plan update and post interim results on the California Water Plan Web site. See Box 4-7 (Crafting Sample Response Packages) for two examples of how response packages can be combined with baseline scenarios.

A significant part of the proposed analytical approach is the addition of quantitative comparisons for different response packages of resource management strategies. This performance evaluation of various mixes of strategies under plausible future scenarios will provide planners unprecedented access to relevant technical information and new insights. This quantitative insight can be used to help guide investments in regional and statewide water management actions. To help focus the quantitative analyses, DWR and stakeholders have developed a list of evaluation categories that represents the technical information required to compare response packages (see Table 4-5 Evaluation categories for assessing achievement of water management objectives).

In the next California water plan update, each baseline scenario will be used to test a number of different regional response packages, that is, different mixes of resource management strategies.

Initial Insights

Three baseline scenarios offer a useful view of how significantly water demand can vary with even relatively conservative estimates of different key factors. This idea will be developed further and refined during analyses for the next water plan update. **The results from these preliminary scenarios illustrate three significant points for water planning in California:**

- **Total demand for water in California in the year 2030 can vary a great deal. Even with relatively conservative adjustments in some key parameters, estimates of state-wide demand vary by almost 4.5 million acre-feet per year.**
- **Urban demand increases in all three scenarios; whereas, agricultural demand decreases in all three scenarios.**
- **Water demand changes differ between regions and by scenario.**

Better quantitative information is needed to assess how these changes could affect California if they are not addressed, and to compare the merits of different management strategies to prepare for these expected changes.

Changes to Consider When Preparing for the Future

When predicting changes, the following activities highlight those factors that should be considered for regional and statewide water plans for the next 25 years.

When planning to accommodate change, it is useful to consider two categories of how change occurs: gradual and sudden. These two characteristics can inform how best to prepare for and respond to changes. Gradual changes can include things like variation in population by region, shifts in the types and amount of crops grown in an area, or changes in precipitation patterns. Sudden changes can include episodic events such as earthquakes, floods, droughts, equipment failures, or intentional acts of destruction. The nature of these changes and their potential impacts on our water management systems can have a big influence on how we prepare to respond to them.

Table 4-5 Evaluation categories for assessing achievement of water management objectives

Water management objective	Evaluation category	Information source
Increase water supply, reallocate supplies or manage demand (all use sectors)	Urban, agricultural, and environmental reliability	Water portfolio / flow diagram; water management/system analysis; inventory of new projects
Improve drought preparedness	Urban, agricultural, and environmental reliability	Water management/system analysis
Improve operational flexibility	Urban, agricultural, and environmental reliability	Data monitoring/compilation and system analysis
Improve water quality (all use sectors)	Risks to human/ecosystem health and agricultural production	Water management/system analysis
Reduce groundwater overdraft	Salinity intrusion Subsidence Groundwater levels (long term)	Data monitoring/compilation and system analysis
Reduce flood impacts	Flood risk	Economic analysis and system analysis
Environmental benefits	Fisheries (populations and habitat) Native habitat/vegetation Wildlife (populations and habitat)	Data monitoring/compilation, biological opinion, and system analysis
Energy benefits	Energy availability	Data monitoring/compilation and system analysis
Recreational opportunities	Quantity, quality and variety of water-based recreation	Data monitoring/compilation and system analysis
Other considerations	Catastrophic vulnerability	Economic analysis and system analysis
	Third party impacts	Economic analysis and system analysis
	Economic/financial	Economic analysis and system analysis
	Public Trust and environmental justice	Participation in planning; assistance to low-income and disadvantaged communities

Sources for Gradual Change

The following categories are expected to change significantly, some dramatically. However, they will likely occur gradually over time. This type of change allows planners to be flexible regarding when management responses are implemented. Understanding the uncertainties around the future changes and the risks associated with these inaccuracies can help determine a prudent mix of management actions.

Future Landscape (Land Use Patterns)

The way that we use land (the types of use and the level of intensity) relates directly to water use, water supply, and water quality. It is impossible to predict precisely how land will be used in the future. By better understanding the uncertainties about land use change, we can plan to accommodate future changes more successfully.

Projecting current trends has been the traditional method for estimating future water demand. However, resource limitations and many economic, environmental, and social factors can cause future conditions to vary significantly from existing trends. For example, changes in job conditions can force people to move from one region to another or from state to state. Changes in the world food market can influence California farmers to alter crop types and crop acreage over time. Advances in scientific understanding of the environment can influence methods for habitat restoration or alter targets for instream flows. Many factors like these can lead to very different land and water use patterns than what may be expected by simply projecting current trends.

We do not currently have the capability to accurately predict a large number of factors that can influence future urban, agricultural, and environmental land and water use patterns. Although it is difficult to quantify some of the specifics, water managers still can prepare for these future uncertainties by formulating a diversified portfolio of complementary resource management strategies.

Even if planners are fairly sure that certain land use changes will occur in a specific area, the timing of those changes can be very uncertain. For example, an estimate that the population of a community will grow to be 500,000 people by 2030 gives planners some useful information. However, if they know that the timing is uncertain regarding when the population will be reached, they are wise to choose management strategies that can be implemented easily on a flexible timeline to accommodate actual population change over time.

Urban Use

According to DOF, California's year 2004 population of more than 36.5 million is expected to reach 48 million by year 2030. However, actual population growth will certainly be more or less than this estimate. More people lead to more urban development, which often changes urban runoff characteristics and water quality. For the California Department of Parks and Recreation, more people mean more demand for water-based recreation, some of which affect lakes that also serve as reservoirs for drinking water. This increasing mixed use raises concerns about the quality of those drinking water sources. (See Volume 2 Chapter 20 Urban Land Use Management and Chapter 24 Water-dependent Recreation.)

California's automobile-dependent lifestyle is reflected in the state's post-World War II urban development. Patterns are characterized by fragmented and segregated land uses, low-density residential and strip commercial development, and a lack of connectivity within and between neighborhoods that use large quantities of land per capita. This style of development has led to consumption of prime farmland and the water appurtenant to that land, open space, or natural habitat and an increased impact on other natural resources. Larger residential parcels tend to consume more water per capita than do smaller parcels. Large amounts of impervious surfaces such as roads and parking lots can degrade water quality and increase local flooding and urban runoff, alter streamflow and watershed hydrology, reduce groundwater recharge, and increase stream sedimentation. It also increases the need for infrastructure to control local storm runoff.

More population growth can also produce additional domestic wastewater discharges and urban runoff, which may in turn contaminate natural water bodies used as drinking water sources. Future water demands can vary widely depending on how urban land use patterns develop. Providing a growing population with a sufficient, affordable, safe, and reliable water supply is a major challenge facing local agencies and governments, especially in light of other challenges like potential water quality degradation that tend to diminish water supply (see Volume 4 Reference Guide article "General Plan Guidelines Chapter 2: Sustainable Development and Environmental Justice").

Agricultural Use

California agriculture will continue to consume more water than is consumed by all household uses for the foreseeable future. As population increases, the need for food and fiber crops also will increase. Over the last 20 years, some water has been redistributed from the production of food and fiber to environmental and urban uses. Furthermore, historically available water supply for agriculture and other uses has been reduced due to continued groundwater overdraft or environmental restrictions in some areas.

California's agricultural production is large, efficient, and diverse, producing more than 350 commodities. California leads the nation in production for 75 crop and livestock commodities, and 13 of those commodities are produced solely within this state. In addition, according to the 1997 Census of Agriculture's ranking of market value of agricultural products sold, 8 of the nation's top 10 producing counties are in California. The state grows more than half of the nation's total fruit, nuts, and vegetables, making California a net exporter of food to the rest of the United States and the world. The California Department of Food and Agriculture (CDFA) estimates that 14 percent of California's agricultural production is exported to other countries.

California has approximately 80,000 farming operations and about 27.6 million acres of farmland, about 9 million acres of which are irrigated. Agricultural land in California has been gradually shifting to urban or other nonagricultural uses. From 1990 to 2000, about 500,000 acres were converted from agricultural to urban or nonagricultural uses. Population growth and nonagricultural forces drive land use conversions (Kuminoff and others 2001). It is uncertain at what rate this land conversion will continue in the future. If farm-to-urban conversion continues to increase at the same per capita rate, approximately 700,000 acres of additional California farmland would be converted to urban use per decade. By 2030, the total conversion would be 2.1 million acres or about 10 percent of the California farmland that was in production in 2000 (Brunke and others 2004).

Although agricultural acreage may decline and will be relocated somewhat by urban development, yield growth in the quantity of agricultural crops produced per acre of land may continue to increase and will probably increase the dollar value of California food production over the next 30 years. Yield growth is expected to occur as a result of technological advances and more multicropping (harvesting multiple crops in a year on the same land), and may also be affected by the impacts of global climate change. In addition, the economic value of crops per acre-foot of water has increased in the past and is expected to continue to increase. Irrigation efficiencies have increased as more growers use drip and sprinkler irrigation. Also, there has been a shift toward agricultural commodities that generate more economic value per unit of water used to produce the commodity.

Since December 31, 2002, tail water discharges and storm water runoff from irrigated agriculture and timber harvesting areas must be monitored. Along with urban runoff, the U.S. Environmental Protection Agency has identified agricultural runoff as the most serious threat to water quality in the country. Municipal and industrial wastewater and even some urban runoff are already formally managed and regulated. However, agricultural runoff and agricultural drainage, especially in the Central Valley, will remain significant and potentially expensive challenges, with no obvious or simple solutions.

Groundwater subjected to overdraft is not a sustainable source of water. The cumulative effects of overdraft and water transfers diminish the reliability and sometimes the quality of irrigation water for food production. Agriculture cannot easily rebound in years of adequate water supply if surface water supplies are greatly curtailed during dry years and affordable groundwater is not available. Growers of permanent crops are particularly at risk. Even growers of annual crops may be unable to obtain long-term loans or short-term credit if they do not have access to a dependable water supply.

Future agricultural water demands can vary widely depending on future agricultural land use changes, crop selection and farming practices. Agricultural water demand is significantly driven by the crop mix grown in the state. Agricultural operations are businesses that seek to produce food and fiber profitably. Global markets, rather than water prices, generally dominate the grower's decision regarding which crop to grow. The grower considers the relative prices of agricultural commodities, the costs and regulations associated with labor, the costs of inputs needed to produce the crop, inter-state and international exchange rates (about 18 percent of California's agricultural production in value terms is exported to other states and countries), and the security of the water supply.

AB 2587 (Stats 2002, Ch. 615) requires the California Water Plan to estimate the water demand needed to substantially continue agricultural production in California. A key phrase in the law is "neither the state nor the nation should be allowed to become dependent upon a net import of foreign food." In particular, the law specifies that DWR consider a future scenario under which agricultural production in California is sufficient to assure that the state is a net food exporter and that the net shipments out of state are enough to cover its traditional share of "table food" use in the United States (assumed by law to be 25 percent) plus "growth in export markets." For the next California water plan update, DWR will examine the AB 2587 analysis based on a food forecast prepared by CDFA, as required by the bill. The CDFA food forecast was not available for Update 2005 because of time and resource limitations.

The University of California Agricultural Issues Center prepared "Future Food Production and Consumption in California under Alternative Scenarios" (see Volume 4 Reference Guide). The report concluded that, based on economics, California agriculture will continue to produce substantial quantities of food crops. The value of California food production will more than keep up with rising population and income growth in California and the rest of the United States.

Environmental Use

Beyond the broad public benefits of maintaining a vital ecosystem, ecosystem restoration serves to improve California's natural water management infrastructure. As we learn more about the link between watersheds, water management, and the health of the environment, the benefits of restoring and protecting California's ecosystem to water supply reliability and water quality improvements are becoming more evident. As actions to restore ecosystems help increase the health and abundance of species protected under the State and federal Endangered Species Acts, there will be fewer ESA conflicts. As ecosystems like wetlands and sloughs are restored, their natural pollutant-filtering capabilities will improve water quality. As floodplains and seasonal lakes and ponds are restored, groundwater recharge can increase. In addition to protecting the public's long-term interest in sustaining natural habitats, investments toward a healthy ecosystem also can contribute to a more reliable, better quality water supply.

The major issues facing ecosystems statewide are aquatic and riparian habitat degradation and freshwater biodiversity declines that are directly linked to:

- physical alterations to habitat associated with on-stream dams, diversions, levees, and bank armoring;
- deterioration of water quality including temperature, pollution, and low dissolved oxygen;
- the introduction of non-native invasive species; and
- long-term climate change.

Over the past century, the scope of these threats has increased dramatically, mirroring human population growth and demand for services provided by and within freshwater ecosystems (transportation, irrigation, recreation, land for development, municipal and industrial water supplies, and energy production).

In rural areas, the main pollution sources often come directly from land use practices both present and past. As an example, the Sierra Nevada Ecosystem Project notes the adverse impact that hydraulic mining, which ceased during the 19th century, is still having on numerous Central Valley rivers. In addition, logging and related road cuts are a major cause of high sediment loads in some North Coast streams. Roads cause significant erosion within watersheds throughout coastal and inland areas. Grazing impacts, such as increased erosion, loss of streamside vegetation, reduction of groundwater recharge ability in mountain meadows, and nutrient inputs, also have contributed to an overall water quality degradation.

Introduction of aquatic non-native species harm public health, compete with native fish, and impede or block water deliveries. Because invasive species interfere with natural processes and do not necessarily provide the full range of benefits associated with native species, management of these invasive species is essential.

The potential environmental impacts to marine species and habitats associated with the use of ocean water for cooling power plants is also an issue facing California water managers because existing seawater intakes for power plant cooling are proposed as the source of supply for almost all proposed desalting plants. In general these existing intake systems have had fairly significant impacts on the coastal zone. A number of aging coastal power plants that use once-through cooling from the ocean may cease operation in the future because they are inefficient. Also, as a result of changes in power plant cooling technology, power plants may convert to a "dry" cooling system. Future technologies used in coastal power plants will affect the ability to use power plant cooling systems to dilute the desalination salt concentrates resulting prior to discharge to the ocean.

How these factors will continue to influence environmental land use is unknown. A challenge is to protect and improve the environment given the continued need for water for urban and agricultural use, problems with non-native species, water quality concerns, and climatic variability. We expect that future environmental water demands can vary widely depending on how land use patterns change in the future and the effectiveness and efficiency of current and planned ecosystem restoration efforts. (For more information, see Volume 2 Chapter 9 Ecosystem Restoration strategy in and Volume 4 Reference Guide article, "Considering Water Use Efficiency for the Environmental Sector.")

Sources for Sudden Change

Some events may or may not occur within the planning horizon, but when they do occur, they can cause major impacts on large segments of the population or the environment. Natural causes or intentional acts can cause major disruption to water infrastructure. A drought, flood, earthquake, wildfire, system malfunction, or unintentional chemical spill is beyond our control, even if the strictest safety measures are in place.

Sooner or later, all of these extreme events will strike somewhere in California. The major uncertainties are when and where they will strike and how severe they will be. Will a future drought be similar to a past drought or will it be longer and more severe? Will the next earthquake cause even greater damage? Will the next levee failure in the Sacramento-San Joaquin River Delta cause catastrophic damage to the Delta and disrupt the delivery of a major portion of the state's water supply?

Formulation and implementation of strong integrated regional water management plans can lessen the impacts of extreme events. State, regional, and local entities can prepare risk assessments to aid decisions on how much protection they can afford to build into their system and in which management strategies to invest. The following sources of sudden change should be considered in preparing integrated regional water management plans.

Delta Vulnerabilities

The Sacramento-San Joaquin River Delta is highly susceptible to flooding. The Delta includes 70 islands and tracts, most of which have land surfaces at or below mean sea level. These islands and tracts are protected from the constant threat of inundation by about 1,100 miles of levees. Subsidence is occurring on most of the islands which serves to lower their land surface with time, thereby increasing the risk and consequence of flooding.

Most of the Delta's levees do not meet modern engineering standards and are highly susceptible to failure. Levees are subject to failure at any time due to seepage, piping, slippage, subsidence/sloughing, or earthquakes, including during dry weather (see section below for discussion of the threat posed by earthquakes to Delta levees). The Upper Jones Tract levee failure of June 3, 2004, is the most recent example of a levee failure during dry weather. The Jones Tract failure may have occurred due to a problem with piping or with the levee's foundation, although the exact cause is unknown. Levee failures in the Delta can also occur during periods of high tides, high winds, and high water.

Levee failures and flooding in the Delta are not rare occurrences. Figure 4-6 (Map of flooded islands in the Delta for different high flow periods) shows flooding in the Delta, from 1967 to 1992. Each of the Delta's 70 islands and tracts have flooded at least once since they were originally dewatered. About 160 individual levee failures have occurred over the past century. Climate change is causing sea levels to rise and may also increase the magnitude of floodflows. Major levee failures are difficult and expensive to repair. In some cases the cost to remove the flood water and repair the damage greatly exceeded the appraised value of the flooded land. Among many possible consequences, Delta levee failure could result in the temporary or long-term disruption of the water supply for about two-thirds of the state's residents and for about half of the state's irrigated agriculture. Levee failure can cause large amounts of saline ocean water to be drawn into the Delta when an island floods. Water supply pumping operations in the Delta for the State Water Project (SWP), Central Valley Project, and other supply systems must stop when a large amount of ocean water is drawn into the Delta and salinity levels in the Delta increase to unacceptable levels. Water supply pumping operations can be restarted when salinity returns to acceptable levels. Salinity conditions can take many months to return to normal depending on the amount and location of levee failures and hydrologic conditions.

Droughts

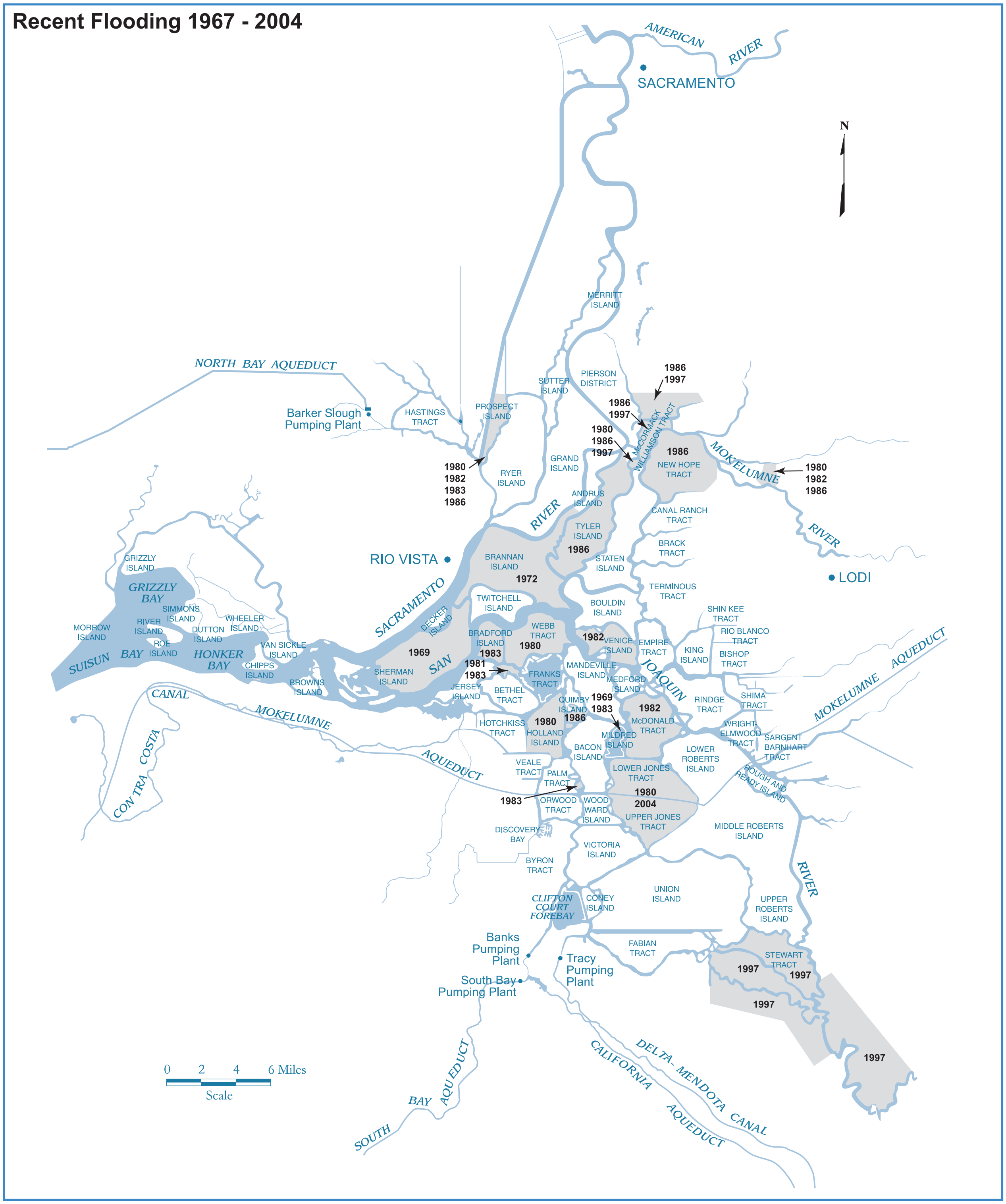
California's most recent severe statewide drought was from 1987 through 1992. In planning water supplies for future needs, the hydrologic record of the past century may not be a reasonable measure of future climate conditions. The state's available hydrologic record is rather short for determining hydrologic risks; it traces back only about 100 years with mostly qualitative information extending back another 100 years. Tree ring studies have shown extensive dry periods far exceeding the 6-year maximum drought recorded during the last century. (See Volume 4 Reference Guide articles "Severity of Extreme Droughts in Sacramento and San Joaquin Valley" and "Planning for Extreme and Prolonged Drought Conditions.")

Floods

Flood magnitude in a watershed depends on several factors such as the intensity and duration of precipitation, location of the storm center, area of precipitation, rain on snowpack, and antecedent soil moisture. The most severe storms for large watersheds are slow-moving frontal storms, with a long southwesterly fetch extending from Hawaii, commonly referred to as the "pineapple express." The most severe storms for smaller watersheds in mountain areas are generally intense thunderstorms.

In January 2005 DWR released the report, "Flood Warnings: responding to California's Flood Crisis", which describes the current risks to the Central Valley from flooding. This report identifies several factors that have put public safety and the State's financial stability at risk for even greater calamity in the future (Box 4-8 Flood Risks Identified in 2005 'Flood Warnings' Report).

Figure 4-6 Map of flooded islands in the Delta for different high flow periods



Levee failures and flooding in the Delta are not rare. Each of the Delta's 70 islands and tracts has flooded at least once since originally dewatered. Major levee failures are difficult and expensive to repair, in some cases exceeding the value of the flooded land.

Earthquakes

Water control and management structures including Delta levees are vulnerable to failure, especially during earthquakes. Because Delta levees and the California Aqueduct system span a large area, their vulnerability to an earthquake is higher than that of an individual structure. Figure 4-7 (Map of San Francisco Bay Region earthquake probability) illustrates the location of major faults in the vicinity of the Delta and the probability of an earthquake of a selected magnitude from those faults.

Water collection and delivery systems in many other areas of the state are at risk of damage or failure due to earthquakes. Several water districts already have plans in place and have taken action to reduce earthquake impacts. Some measures include seismic vulnerability assessment, water supply augmentation, delivery system improvement, and groundwater recharge programs. For example, Calleguas Municipal Water District lost its water supply when the 1994 Northridge earthquake damaged its single feeder pipeline from the SWP. The North Los Posas Storage Program (210,000 acre-feet capacity, groundwater recharge program) now augments the water supply to this district to help lessen risks posed to the area's water supply by earthquakes.

Box 4-8 Flood Risks Identified in 2005 'Flood Warnings' Report

Aging facilities. California's Central Valley flood control system of levees, channels and weirs is old. Many levee reaches were built more than a century ago on foundations that are subject to seepage and movement. Over time, the levee system has significantly deteriorated, pa rtly due to deficiencies in the original design and partly due to deferred maintenance.

Data uncertainties. Traditionally, levee heights and channel capacities have been designed using historical data related to precipitation and runoff. However, due to either limited historical data or climate change, the general trend is for floodflows to be higher than anticipated.

Susceptibility to flooding. The potential impacts on people and communities of a single failure or multiple failures are catastrophic. These risks tend to be disproportionately higher in rural and economically disadvantaged communities that are often unable to invest in flood control improvements.

Increasing potential for flooding. Much of the new development in the Central Valley is occurring in areas that are susceptible to flooding. In some cases, land use decisions are based on poor or outdated information regarding the seriousness of the flood threat.

State liabilities for local decisions. Local land use decisions that allow developments in floodplains protected by the State-federal levee system in the Central Valley greatly increase the risk of State liability for loss of life and property damage.

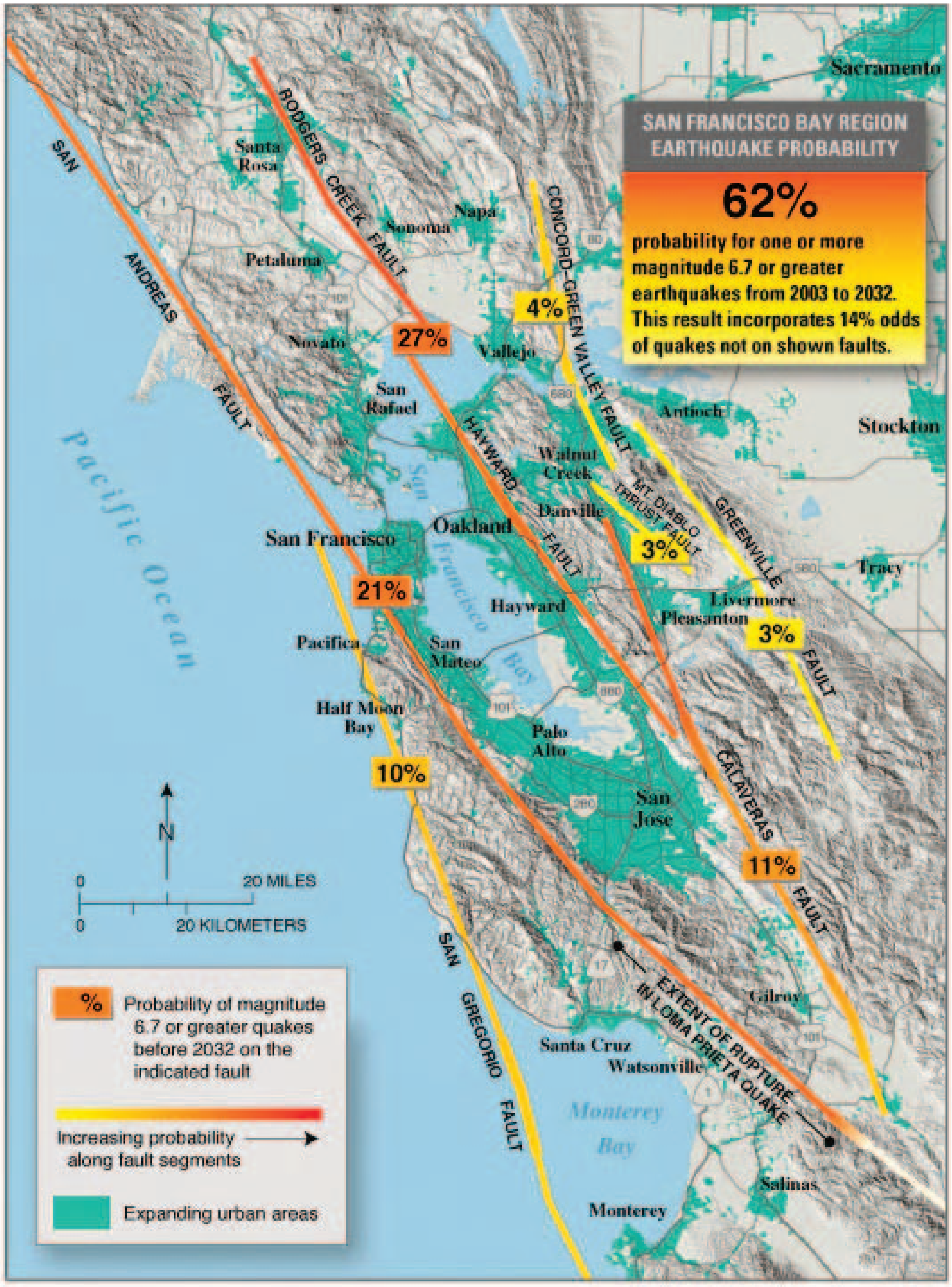
False sense of security. People who live and work behind levees have a false sense of protection. Many believe that the levees will protect them against any level of flooding. During a typical 30-year mortgage period, there is a 26 percent chance that a homeowner living behind a levee will experience a flood larger than the 100-year flood. This risk is many times greater than the risk of a major home fire during the same period.

Increasing State liability. As the risks of levee failure and corresponding damage increase, California's courts have generally exposed public agencies, and the State specifically, to enormous financial liability for flood damages. The November 2003 Paterno ruling held the State responsible for defects in a Yuba County levee foundation that existed when the levee was constructed by local agricultural interests in the 1930s.

Decreased funding. At a time when flood control maintenance and improvement efforts should be increased, the investment in flood management has instead been reduced at all levels of government. Local governments in California have been severely restricted by two constitutional amendments regarding the use of property tax or benefit assessments to generate revenue (Propositions 13 and 218). The federal government in 1996 reduced the maximum that it would pay for the cost of new flood control projects, from 75 percent to 65 percent of the total project cost.

Source: California Department of Water Resources. 2005. Flood Warnings: Responding to California's Flood Crisis. www.publicaffairs.water.ca.gov/newsreleases/2005/01-10-05flood_warnings.pdf

Figure 4-7 Map of San Francisco Bay Region earthquake probability



Probability of a 6.7 magnitude earthquake within 30 years in Bay Area *(2003 earthquake probability study - USGS)*
Water control and management structures including Delta levees are vulnerable to failure, especially during earthquakes. Because Delta levees and the California Aqueduct span a large area, they are more vulnerable to earthquakes than are individual structures.

Wildfire

Wildfire can result in short-term and long-term disruption to a water supply system and other resources. Wildfire can damage project facilities, including burning wooden flumes and power transmission lines. The loss of vegetation on the watershed can change runoff patterns, reduce natural water storage, increase sedimentation, and create other long-term impacts.

Facility Malfunction

Deferred maintenance and an aging infrastructure of State, federal, and local water projects present risks to public safety, water supply reliability, water quality, and ecological health. The infrastructure includes key water conveyance and delivery facilities and drinking water and sewage treatment systems that are subject to routine malfunction, short-term outage, or catastrophic failure.

The SWP is more than 30 years old, the federal Central Valley Project is more than 50 years old, and some local facilities are more than 100 years old. Some of their facilities have surpassed their design life and require significant rehabilitation or replacement. In recent years infrastructure failures have disrupted water deliveries. Much of the equipment and large fabricated components are unique. Spare parts would not be readily available if a sudden failure were to occur; it is generally impractical to store extremely large spare parts on site. The replacement of many of these items from sources outside the United States is time-consuming, thereby increasing the vulnerability of the projects.

Water systems are often interconnected or have coordinated operations for optimal, multiple benefits. When an operation of one system depends on the smooth operation of another, the successful operation of the complete system can become vulnerable to a failure in either part. The failure of the Jones Tract levee in the Delta was a reminder of the vulnerability of the Delta levee system and the interconnected nature between Delta levees and water supply operations. This incident required DWR and the U.S. Bureau of Reclamation (USBR) to take the following actions immediately to protect water quality and water supply operations in the Delta:

- USBR increased releases of fresh water from Shasta Dam to help control salinity and opened the gates of the Delta Cross Channel to move Sacramento River water into the central Delta to repel seawater intrusion.
- DWR and USBR reduced pumping at their south Delta export pumps to reduce the intrusion of sea water.
- DWR monitored Delta water quality at more than 20 sites and channel velocity changes in the Jones Tract area of the Delta.
- DWR conducted flood damage control efforts, reconstructed and repaired damaged levees, and removed flood water from the tract.

Chemical Spills

Truck and railroad tanker accidents and other unintentional spills can release toxic chemicals into California's rivers and other conveyance facilities. For example, a 1991 railroad accident near Dunsmuir resulted in a toxic spill that destroyed all aquatic life within a 38-mile reach of the Sacramento River above Shasta Dam. A similar accident in another location could shut down a community's drinking water supply for an extended period of time.

Intentional Disruption

Vandalism is defined as malicious destruction of property. Vandalism to water infrastructure could be acts like defacing concrete structures and important notice boards, stealing copper fittings and aluminum handrails, shooting at a turnout structure gate, dumping pesticides or other chemicals into California waterways, or dumping heavy material into the aqueduct. Most vandalism occurs in rural areas away from residential neighborhoods and frequent security patrols. For example, in the early 1980s, dredging of a one-mile stretch of the California Aqueduct revealed concrete blocks, farm equipment, and stolen vehicles. A similar stretch in the Delta-Mendota Canal in the early 1990s revealed more than 80 abandoned vehicles.

Terrorist acts are meant to cause major damage and loss of life, and there is a risk that water infrastructure could be targeted by terrorists. Many agencies have responded by reducing access to both the water-related facilities and information about the facilities that could be used by terrorists. Increased security is needed to reduce the chances of terrorism causing outages in water service and other damage caused by water system failures.

Cyber threats pose a serious potential impact to the operational capability of water delivery and treatment systems. Many new water delivery and treatment systems are SCADA (Supervisory Control and Data Acquisition) controlled through the Internet. The operational costs of these modern systems are low because of remote access capability from a single command center to operate segments of or the entire system. However, the entire operation becomes vulnerable to international hackers or cyber terrorists. The SWP, unlike many other water delivery systems, has a control system independent of the Internet.

Most water supply infrastructure was constructed at a time when vandalism, illegal dumping, and the threat of terrorism were uncommon. Fencing around the facilities and structures was installed primarily to prevent accidents. Today, the absence of active patrolling and lack of fencing along the waterways is attributed to the high rate of dumping in those areas.

Global Climate Change

As a result of global climate change, California's future hydrologic conditions will likely be different from patterns observed over the past century. Predictions include increased temperatures, reductions to the Sierra snowpack, earlier snowmelt, and a rise in sea level, although the extent and timing of the changes remain uncertain. These changes could have major implications for water supply, flood management, and ecosystem health. The prospect of significant climate change warrants examination of how California's water infrastructure and natural systems can be managed to accommodate or adapt to these changes, and whether more needs to be done.

Managing water resources with climate change could prove different than managing for historical climate variability because climate change could produce hydrologic conditions, variability, and extremes that are different from what current water systems were designed to manage; may occur too rapidly to allow sufficient time and information to permit managers to respond appropriately; and may require special efforts or plans to protect against surprises or uncertainties.

For over a decade, scientists have been publishing formal, peer-reviewed recommendations for integrating the results of climate change research into policy. The Public Interest Energy Research Program established a regional climate change research center (Box 4-9 PIER Program and Climate Change Research). The Pacific Institute, in a literature search report for DWR, summarized recommendations for coping and adapting to climate change from key peer-reviewed publications. The Pacific Institute's report "Climate Change and California Water Resources: A Survey and Summary of the Literature" and a DWR report on climate change impacts and recommendations for further research, "Accounting For Climate Change," are included in Volume 4 Reference Guide. The University of California, Davis used the CALVIN model to evaluate how California's water system might adapt to long-term climate warming (see Box 4-10 CALVIN: An Analytical Tool to Evaluate Effects of Climate Change).

At present, the extent of climate change impacts is uncertain. As more sophisticated tools are developed and more studies are completed, better quantification may be possible. One approach for planning for uncertainties associated with climate change is to perform sensitivity analyses with different assumptions about potential future conditions. Incorporating flexibility and adaptability into our current system can strengthen our ability to respond to change. Flexible systems contribute to beneficial operations both under current as well as future climate conditions by allowing management adjustments or midcourse corrections without causing major economic and social disruptions.

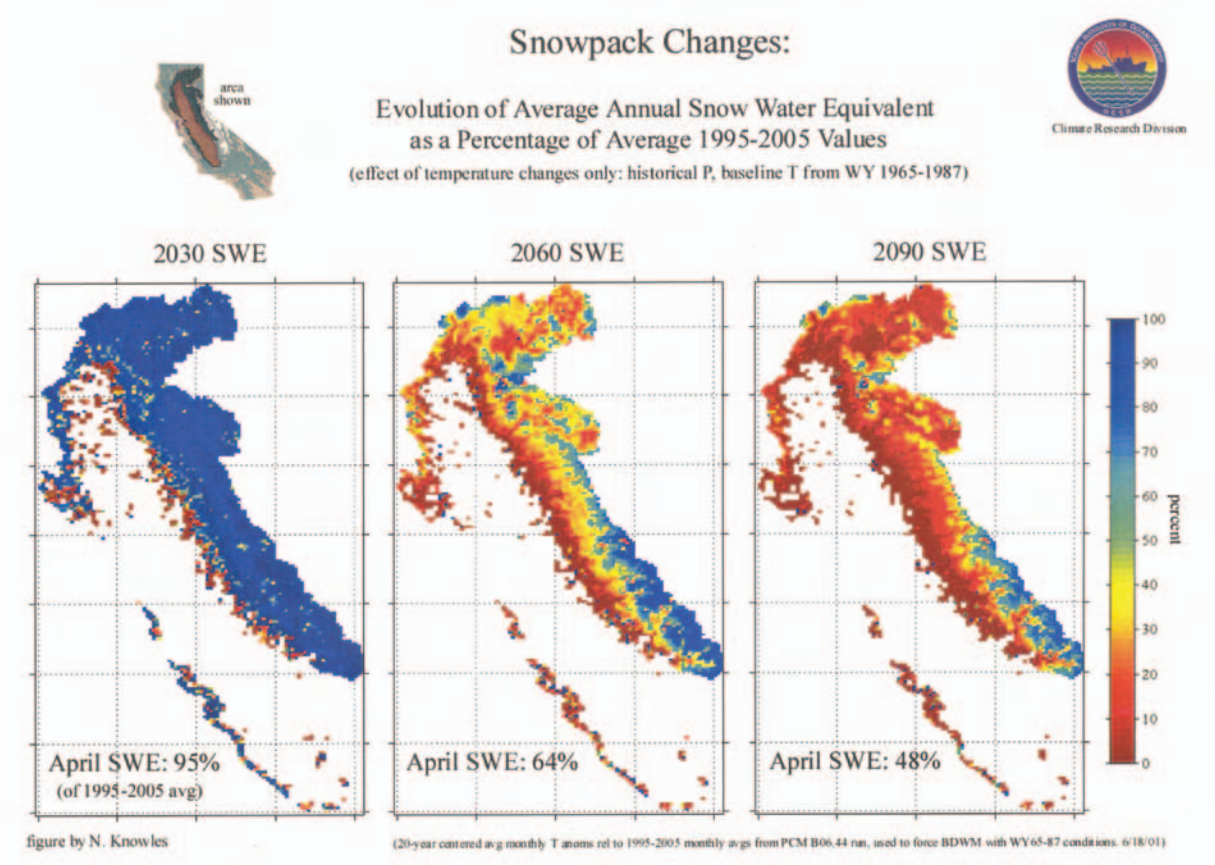
Box 4-9 PIER Program and Climate Change Research

In conjunction with affected state agencies, the Public Interest Energy Research Program administered by the California Energy Commission has developed and is implementing a climate change research plan for California. The PIER Program established a regional climate change research center with the goals of:

- Improving the understanding of the possible physical and economic impacts of climate change
- Developing robust adaptation and mitigation strategies for California.

In support of future updates of the California Water Plan, the California Climate Change Research Center is funding (1) the development and maintenance of a comprehensive climatic database for California and the analysis of meteorological and hydrological trends; (2) the monitoring of meteorological and hydrological parameters in some key remote locations using innovative remote sensing devices; (3) the development of climate projections for the state using regional climate models at levels of resolution appropriate for water resources impact analyses; and (4) the study of water resources impacts under different climatic projections. The Department of Water Resources is a key co-sponsor of these research activities.

Figure 4-8 Model simulation of potential changes in snowpack during 21st century



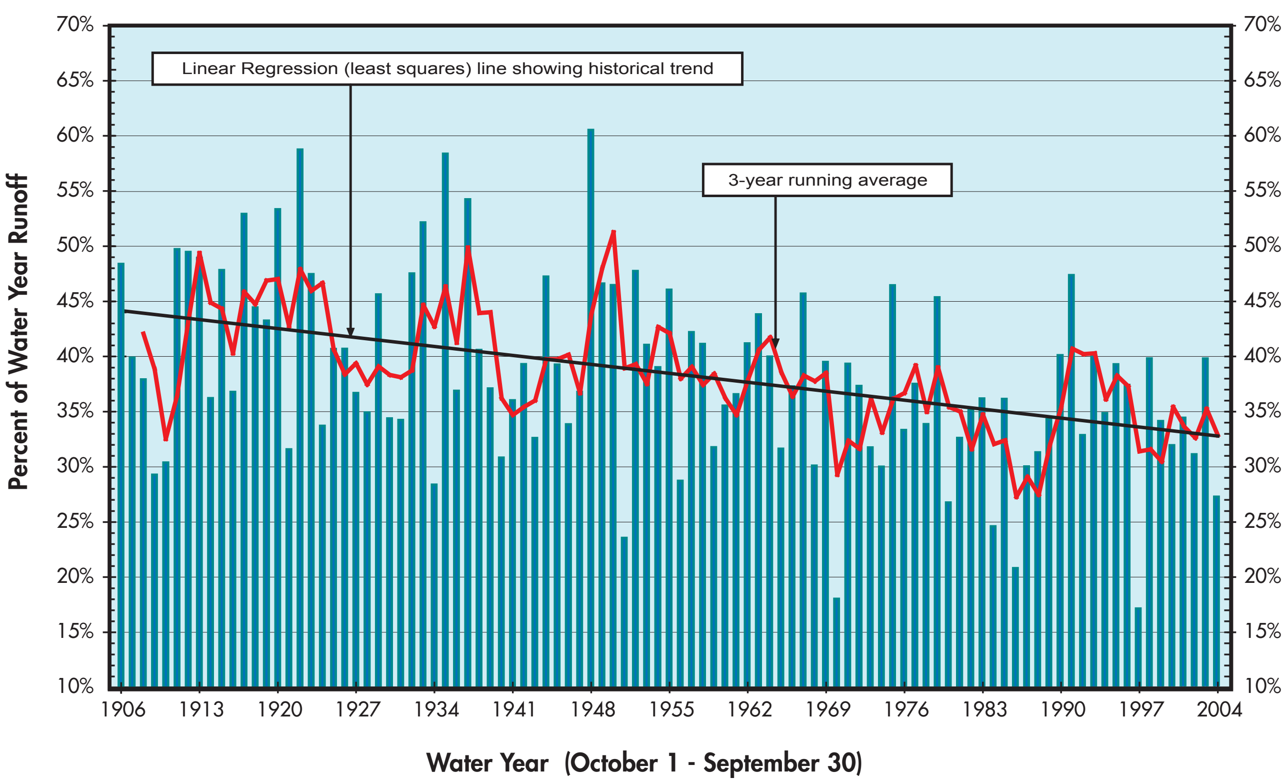
California relies on snowpack as a major part of annual water storage. Computer modeling of global climate change scenarios predict significant reductions in future snowpack. A 52 percent reduction in the annual April through July runoff would occur for a 2.1 degree C (3.8 F) of warming. (Source; Knowles and Cyan 2001)

Box 4-10 CALVIN: An Analytical Tool to Evaluate Effects of Climate Change

From 1998–2003 the University of California, Davis (with funding from the Resource Agency, CALFED, and California Energy Commission) developed a preliminary analytical tool, named CALVIN, to quantify the potential of integrated long-term solutions for California water management. The tool integrates existing surface water, groundwater, and water demand data in an integrated economic-engineering framework for California's intertied water system (covering 92 percent of California's population and 88 percent of its irrigated area).

In developing the computer model, significant weaknesses and gaps in water data were identified and documented. The model and its results have been peer reviewed and show preliminary insights into economically promising possibilities for California water management. More importantly, the tool demonstrated concepts in advanced data management, documentation, and analysis that may be useful for future statewide and regional water policy and planning analysis. The CALVIN model has been applied preliminarily to examine statewide potential for regional and statewide water markets and how California's water system might adapt to long-term climate warming (through the Public Interest Energy Research Program).

Figure 4-9 Sacramento River April-July runoff in percent of water year runoff



Historical records reveal changes in runoff pattern from April through July in a number of California rivers. Since the 1950s, the percentage of total annual runoff occurring during these months has declined progressively, an indication of earlier snowmelt and warmer temperatures.

Some of the expected impacts of global climate change are discussed in the following sections.

Snowpack Changes

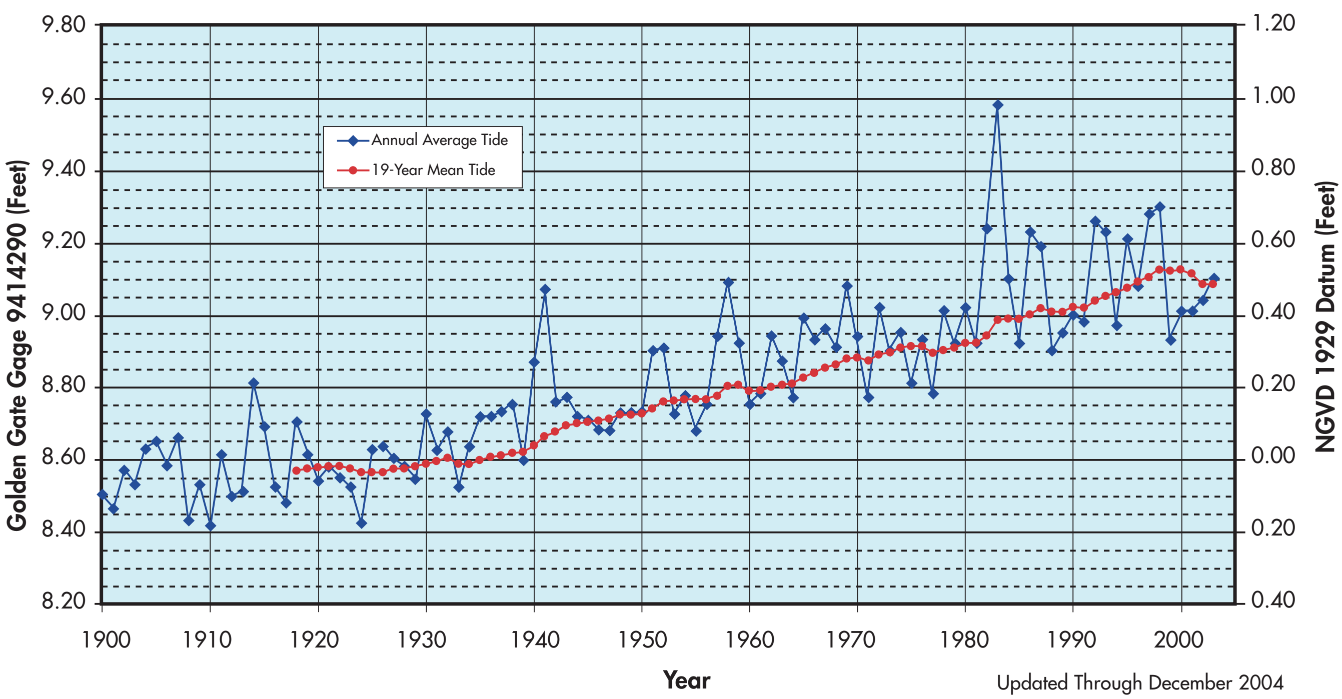
California's relies on snowpack as a major part of annual water storage. Annual runoff from the Sierra Nevada during April through July averages 14 million acre-feet and comes primarily from snowmelt. Computer modeling of global climate change scenarios predict significant future reductions in the Sierra snowpack. A reduced snowpack will reduce the total water storage for the state. Figure 4-8 (Model simulation of potential changes in snowpack during the 21st Century) shows a 52 percent reduction in the annual April through July runoff for a 2.1 degree C (3.8 F) of warming, well within the 1.4 to 5.8 degree C (2.5–10.4 F) range predicted by global climate models for this century.

Changes in the timing of snowfall and snowmelt, as a result of climate change, may make it more difficult to refill reservoir flood control space during late spring and early summer, potentially reducing the amount of surface water available during the dry season. Changes in reservoir levels also affect lake recreation, hydroelectric power production, and fish habitat by altering water temperatures and quality. Reductions in snowpack may require changes in the operation of California's water systems and infrastructure, and increase the value of additional flood control space in reservoirs.

Hydrologic Pattern

Historical records reveal long-term changes in the pattern of April–July runoff; an example is plotted here for the Sacramento River (Figure 4-9 Sacramento River April-July runoff in percent of water year runoff). From the 1950s to present, the percentage of April through July runoff has shown a progressive decline. This may indicate a decline in the amount of water stored annually in the Sierra snowpack leading to reduced spring and early summer river flows. The same effect is noted to a lesser degree on southern Sierra rivers. While these measurements are consistent with climate change model simulations, more extensive monitoring of runoff and snowpack is necessary for greater understanding of ongoing changes in hydrologic patterns.

Figure 4-10 Golden Gate annual average and 19-year mean tide levels



Global climate change is already leading to sea level rise, which can disrupt coastal communities, ecosystems, and tidal wetland restoration. It can also increase pressure on Delta levees, whose failure would disrupt water supply for about two-thirds of the state's residents and about one-half of its irrigated agriculture.

Sea Level Rise

Global climate change is already leading to sea level rise. Figure 4-10 (Golden Gate annual average and 19-year mean tide levels) shows historical sea level rise at the Golden Gate. During the 20th century, sea levels increased by 0.2 meters (0.7 feet). Models project a median rise of 0.5 meters (1.6 feet) over the 21st century due to climate change (IPCC 2001). Sea level rise could eventually disrupt ecosystems and communities in coastal areas and disrupt ongoing tidal wetland restoration efforts. The biggest impact of sea level rise on California's water supply and tidal wetlands restoration efforts could be in the Sacramento-San Joaquin River Delta. Sea level rise would increase pressure on Delta levees that protect low-lying lands, much of which are already below sea level. A single-foot rise in sea level would increase the frequency of the current 100-year peak high tide in the western Delta to about a 10-year event. Another effect of sea level rise is increased salinity intrusion from the ocean, which could degrade freshwater supplies pumped from the Delta unless more fresh water from upstream reservoirs is released to push back intruding sea water. Sea level rise could also threaten coastal aquifers.

Rainfall Intensity

Regional precipitation responses to climate change remain difficult to determine. If climate change results in larger individual precipitation events, it could affect current reservoir flood control operations and other flood management activities and infrastructure. Watershed protection activities would also be affected because changes in storm intensity could affect water quality and erosion.

Urban, Agricultural, and Environmental Water Demand

Climate change predictions include increased temperatures, as discussed earlier. Plant evapotranspiration increases with increased temperature. Another factor that may affect plant evapotranspiration is atmospheric carbon dioxide concentrations. Long-term increases in worldwide atmospheric carbon dioxide levels are expected to continue for some time. Some laboratory tests indicate that increased atmospheric carbon dioxide concentrations can act to reduce plant water consumption. Most researchers believe that the influence of warmer temperatures on increasing plant water consumption may be partially offset by the effect that rising carbon dioxide concentrations have on reducing consumption. More research is needed in this area.

Aquatic Life

Warmer air temperatures and changes in snowmelt will make it more difficult to manage reservoirs and reservoir releases to maintain rivers temperatures that are cool enough for anadromous fish. Higher water temperatures will also increase chemical and biological reaction rates in water bodies, which could adversely affect aquatic species. Many extensive studies on climate change provide more detailed impacts on the environment.

Changing Policies, Regulations, Laws, and Social Attitudes

This category of potential changes can also include elements of both gradual and sudden change. Evolving policies, regulations, laws and social attitudes have dramatically altered California's water management over the past few decades. Some examples include the CVPIA and State Water Resources Control Board Decision 1641, which require more water to meet water quality standards. Furthermore, additional listing of threatened and endangered species has required more water to address environmental needs.

It is difficult to anticipate precisely how changes in policies, regulations, laws, and social attitudes will affect future water management. However, there are methods that can be employed to consider potential impacts on the system if similar changes were to occur in the future. These kinds of potentially significant changes that are difficult to predict where, when, and what might happen emphasize the value of enhancing regional self-sufficiency and strengthening statewide water management systems to provide more flexibility.

Relationships between Water Operations and Environmental Impacts

Environmental restoration science is a work in progress. Rarely do we have the necessary scientific information on a species, much less an ecosystem, to identify an exact course of action that will restore natural communities and processes. When precious resources and endangered species are involved, we often do not have the time or money to fully develop our scientific understanding before action is needed. Yet, the uncertainty can result in hesitation and delay. Improved understanding of ecological processes can lead to changes in policies, regulations, and laws.

Understanding watershed characteristics allows the use of adaptive management to operate projects and programs that best fit into the ecological settings. In some cases the description of these characteristics will reveal that important infrastructure, programs, or projects are not sensitive to watershed processes or have not been designed to capture the full ecological value of the projects. In these cases reoperation and redesign may greatly improve the watershed compatibility of the projects. (See Volume 2, Chapter 19 System Reoperation and Chapter 25 Watershed Management.)

Changing Plumbing Codes

Future changes in plumbing codes, like the one for installing ultralow flush toilets, could allow use of innovative water fixtures to conserve water. Code changes could expand use of recycled water for various nonpotable uses. These and other changes could alter water use and supplies.

Emerging Contaminants

The nature and impact of contaminants themselves may be changing in the future. Future population growth and demographic changes may further impair the quality of water bodies with both known and emerging contaminants, increasing the risk of drinking water. Demographic change may create larger groups of people, including the very old and the very young, who are more vulnerable to drinking water contaminants. Information on pollutant sources and their impacts is insufficient to adequately respond to existing problems. As new health risk information is obtained, water quality standards may become more stringent to protect health and safety. Reevaluation of health-effects research often leads to re-regulation of known contaminants. Moreover, there is a growing demand from consumers, expressed in opinion surveys as well as in the marketplace, for higher quality water.

Summary

All Californians have strong incentives to promote the development and exchange of better information about how to balance risk and reward related to water resource investments. These types of decisions have never been more complicated and, perhaps, more necessary. Preparing for the future in the face of tremendous uncertainties requires cooperation among all levels of government in California. There is much more to learn about how our complex water management systems work, and how they will respond to a multitude of future changes.

Three baseline scenarios offer a useful view of how significantly water demand can vary with even relatively conservative estimates of different key factors. This idea will be developed further and refined during analyses for the next California water plan update. The results from these preliminary scenarios illustrate three significant points for water planning in California:

1) Total demand for water in California in the year 2030 can vary a great deal. Even with relatively conservative adjustments in some key parameters, estimates of statewide demand vary by almost 4.5 million acre-feet per year.
2) Urban demand increases in all three scenarios; whereas, agricultural demand decreases in all three scenarios.
3) Water demand changes were different between regions and by scenario.

These scenarios clearly suggest that water demands can change significantly throughout the state by 2030. These kinds of changes are best managed using integrated regional water management supported by strong statewide water management systems.